TWENTY TRUCK FUEL & LUBRICANT FLEET TEST PROGRAM

by

Southwest Research Institute
San Antonio, Texas

SUMMARY REPORT

Contract No. DAADO 5-67-C0361

Conducted for

Fuel & Lubricants Division
Coating & Chemical Laboratory
Aberdeen Proving Ground

September 3, 1968

SOUTHWEST RESEARCH INSTITUTE
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An Appendix Report in Two Volumes Has Also Been Published to Supplement This Report.

ABSTRACT

A 20-truck fleet test of general purpose vehicles was conducted with four different engine oils, four gear lubricants, four greases, three brake fluids, an arctic antifreeze, two grades of gasoline, and two compression ignition fuels over a test course ranging from highway operation, hilly cross-country terrain, to operation in deep sand, in order to establish the compatibility of the various test materials with typical vehicles in the Army inventory. In general, the majority of the materials performed satisfactorily although specific compatibility problems were noted with engine oils in the 5-ton truck and gear oils in the 1/4-ton M151 jeeps. Both federal and Military specification brake fluids gave satisfactory operational performance but tended to cause corrosion and gum buildup during inactive periods, whereas a military specification preservative fluid tested caused less corrosion and gum with satisfactory operation within its temperature limits. The military specification antifreeze utilized performed adequately in lower-heat-output engine systems but provided marginal to poor performance in the higher-heat-output engine systems.

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INTRODUCTION

The continual utilization of new and improved Military vehicles requires a constant review and upgrading of the various specifications which control the quality of Military fuels, lubricants, brake fluids, and antifreezes. The field data necessary for determining the need to increase severity requirements of present qualification tests or the need to develop new qualification test procedures are obtained by various methods. Two direct methods come from continuous surveillance of maintenance records and inspection of engines and vehicles returning from field service for rebuild. However, both of these are somewhat subjective since operation conditions, individual vehicle maintenance, type of service, and personnel vary from location to location. The most effective method of obtaining meaninful data is a controlled fleet test involving a representative range of vehicles, materials, operating conditions, and environment.

This fleet test program was conducted by Southwest Research Institute, San Antonio, Texas, for the Fuels and Lubricants Division, Coating and Chemical Laboratory, Aberdeen Proving Ground, Maryland, under Contract Number DAADO 5-67-C0361. The purpose of the test program was to obtain under high-temperature/heavy-duty operation, field performance data on fuels, lubricants, brake fluids, and antifreeze used in general purpose Army vehicles. The program consisted of testing selected materials in a 20-truck fleet operated under a controlled test cycle for a duration of 20,000 miles per vehicle. Evaluation of test material performance was based on laboratory analysis of samples obtained during test and vehicle inspections made during and on completion of test.

OBJECTIVES

The fleet test had three primary objectives:

(1) To determine if the test materials satisfactorily met the vehicle requirements.

(2) To obtain field data in order to determine if the lubricant qualification test procedures correlated satisfactorily with field use results.

(3) To investigate the applicability of spectrometric metals analysis to Army general purpose vehicles.

GENERAL DESCRIPTION OF TEST

Test materials selected for use in the fleet consisted of three MIL-L-2104B and one DEF-2101D engine oils, four MIL-L-2105B gear lubricants, one MIL-G-10924A Amendment 2, and three MIL-G-10924B (one qualified and two experimental) multipurpose greases, three brake fluids (one each meeting Specifications VV-B-680, MIL-H-13910 and MIL-P-46046), and one MIL-A-11755 antifreeze. Fuels used for test included two MIL-G-3056B gasolines of differing induction system deposit (ISD) indices, one MIL-F-45121B (CITE-R) fuel, and a Caterpillar 1-H reference diesel fuel. The fleet consisted of five 1/4-ton, two 3/4-ton, and five 1-1/4-ton vehicles powered by gasoline engines and five 2-1/2-ton and three 5-ton vehicles powered by multifuel engines. Test material-vehicle combinations assigned at the start of test were maintained throughout testing with the exception of the fuels used by the multifuel engines. All multifuel powered vehicles used MIL-F-45121 (CITE-R) fuel during the first 12,000 miles of operation and Caterpillar 1-H reference diesel fuel for the subsequent test period.

Prior to road operation, the fleet vehicles underwent extensive preparation. Upon receipt of the vehicles, the engines were removed, disassembled, the bearings and piston rings replaced, valves lightly ground, all weight and size measurements recorded, reassembled, and then reinstalled in the vehicles. Each gear assembly was removed from the trucks and disassembled to determine that each was clean, free of rust, and in new condition with proper backlash and no indication of wear or corrosion. Where deviations from these conditions existed, corrected steps were taken and will be discussed in more detail later in the report. With respect to chassis components, all universal joints and constant-velocity joints in all the trucks were disassembled, washed, dried, inspected, packed with the test grease specified and reassembled. All wheels were removed from the trucks and the wheel bearings and hubs were washed out with solvent, dried, and inspected for wear or defects. The bearings were thoroughly packed and some surplus grease allowed to remain on the outside of each roller cone assembly. While the wheels were off, new brake cylinder assemblies were installed using complete new cylinders drawn from Army stock. Thermocouples were installed to measure temperatures in the sumps of each axle, transmission, transfer case and engine, plus engine-water-out, engine oil gallery, fuel to and from the engine (multifuel only), and inside a front and a rear wheel brake cylinder (the latter on only one of each model truck). A lead was provided to connect to the thermocouples installed in the front wheel hubs of each truck to measure the temperature of outer bearings, outer races, immediately after the truck was stopped.

The fleet was scheduled for operation over two highway courses and one sand course. The first highway course was essentially level highway involving high-speed operation with a required stop every 32.5 miles at the turn-around points. The second course was through the hill country of South Central Texas characterized by numerous turns through the rolling terrain and low mountains along the Balcones fault. The third course was in deep sand at Padre Island approximately 160 miles southwest of San Antonio. Of the total 20,000-mile operation, 16,000 miles were run on the level highways, 3,600 miles in the hill country, and an additional 400-mile operation was in the sand. A brief description of the test cycle is shown below:

(1) 50-mile break-in, variable speed (35 mph), level road

(2) 3950 miles of high-speed operation on level interstate highway

(3) Mid-test gear inspection

(4) 1800 miles of high-torque operation on hilly roads which required low-gear operation

(5) 200 miles of sand operation at Padre Island using low gears and all-wheel drive

(6) Mid-test gear inspection

(7) 6000 miles of high-speed operation on interstate highway

(8) 1800 miles of high-torque operation on hilly roads which required low-gear operation

(9) 200 miles of sand operation at Padre Island using low gears and all-wheel drive

(10) 6000 miles of high-speed operation on interstate highway.

"An investigation of the applicability of spectrometric metals analysis to Army general purpose vehicles was conducted by the Army Fuels and Lubricants Research Laboratory located on the grounds of the Institute. This investigation, funded through Contract Number DAAD 05-67-0354, formed an integral part of the test program with oil samples being obtained at regular specified mileage intervals."

At the conclusion of the test, the vehicle engines and other pertinent vehicle parts were disassembled for inspection by Institute personnel, Army representatives, and members of various industry-government committees. From these and the mid-test gear inspections, conclusions were drawn on the performance of the various test materials and recommendations made concerning the fuel, lubricant, brake fluid, and coolant requirements of this range of vehicles.

SUMMARY OF RESULTS

At the completion of the test, the engines, gear boxes, and vehicle components were disassembled for inspection by the various review teams. The following is a summary of the results obtained:

Engine Oils—As illustrated in Table 1, engine oils coded CCL-O-144, 145, and 146 were qualified MIL-L-2104B products and CCL-O-147 was qualified under DEF 2101D. The engines were inspected and rated in terms of their total deposits in order to determine overall performance, and a summary of the results is shown in Table 2. The results indicate that all oils performed adequately in the 1/4, 3/4, 1-1/4, and 2-1/2-ton vehicles. However, a compatibility problem was observed with all oils tested in the 5-ton truck engine. It was also seen that use of gasolines having high induction system deposit indices can cause a significant increase in varnish and sludge deposits. In terms of individual oil performance, CCL-O-146 was slightly better than 145 in the gasoline powered and 2-1/2-ton vehicles. CCL-O-144 was essentially equivalent to 145 and 146 in terms of deposits but frequent occurrences of mild liner and ring distress (scuffing, scoring) were noted in almost all engines run with this oil. CCL-O-147 was decidedly inferior to the other three oils. In the 5-ton truck engines (LDS-465A1), CCL-O-145 showed superior performance to both 146 and 147. The engine using 146 was terminated below 15,000 miles due to a cracked block, but it had suffered considerable bearing problems (new set installed at 7,286 miles) due to wear and/or corrosion. Bearing distress was also noted in the other 5-ton vehicle engines. CCL-O-147 exhibited heavy depositing in this engine.

Gear Lubricants—As illustrated in Table 1, there were four gear oils used in this test—CCL-G-148, 149, and 150 which were all qualified MIL-L-2105B products and CCL-G-151 which was a 50/50-percent blend of CCL-G-149 and 150. All gear assemblies were inspected prior to and at the conclusion of the test. In addition, the axle assemblies were inspected after the first 4,000 miles of high-speed highway operation and at 6,400 miles after the first high-torque cycle comprised of hill course operation and 200 miles across the sand at Padre Island. In general, all four lubricants performed satisfactorily in all vehicles except the 1/4-ton M151 jeeps. Eight of the nine jeep axles which completed the test had scoring or ridging on the ring and pinion gear tooth contact surfaces. Also noted was the fact that CCL-G-148 did not adequately inhibit rust. All gear units lubricated with this product had varying degrees of rust, more below the oil level than above. The rusting was predominately on noncontact surfaces since daily operation of these trucks kept the contact surfaces rubbed clean.

Multipurpose Grease—There were four greases evaluated in the test, two qualified and two experimental materials meeting the MIL-G-10924 amendment 2 specification. Examination of the 68 front wheel bearings in trucks, 72 wheel bearings in trailers, and several universal and constant-velocity joints indicated no deficiencies in lubrication and, in essence, no differences between the four greases. There were three bearing failures, all of a typical spall type not attributable to lubricant failure. Therefore, it was concluded that all greases performed equally well.

Brake Fluids—After completion of the test, vehicle wheel cylinders were inspected. It was observed that corrosion was less evident in the cylinders containing the preservative MIL-P-46046 fluid than the cylinders containing the operational VV-B-680 and MIL-H-13910 fluids. Several cylinder pistons in vehicles containing MIL-H-13910 fluid had become frozen during the interval between the end of operation and inspection. Rust buildup in cylinders was due to water pickup-fluid oxidation products attacking the metal components. This situation was magnified in some cylinders by the galvanic action between iron cylinder walls and aluminum pistons.

Antifreeze—On completion of the test, inspection of vehicle coolant systems showed satisfactory coolant performance in the 1/4, 3/4, 1-1/4-ton trucks and marginal performance, evidenced by moderate to heavy rusting in the 2-1/2 and 5-ton trucks. Analysis of the used MIL-A-11755 antifreeze samples indicated that the higher-heat-output engines caused a depletion of inhibitors resulting in the rapid lowering of the antifreeze pH with subsequent attack on metal components.

SPECTROMETRIC OIL ANALYSIS

"A comprehensive description and discussion of this investigation is available in other reports (see bibliography references 1 and 5). In brief, it was found that: (1) atomic emission and absorption spectrometry provides a rapid means of monitoring wear metals and additives in used lubricant samples, Table 3; (2) diesel engine bearing failures could be successfully predicted whereas gasoline engine bearing failures could not be predicted; (3) engine coolant leaks and dust ingestion were readily detected; and (4) other tests emphasizing particle suspension could be used to provide clearer interpretation of the spectrometric analysis." The oil analysis data are shown in Appendix II.

CONCLUSIONS

Based on the results observed during the 20,000-mile fleet test, the following conclusions are made:

Engine Oils

- MIL-L-2104B oils are not applicable to all engines in Army general purpose vehicles since a definite compatibility problem existed between the oils evaluated and the more highly stressed LDS 465A1 engine.

- The engine-fuel-oil compatibility procedures used for qualifying engines for use by the Army are inadequate.

- In terms of specific oil performance, the following ranking can be made:

  (1) CCL-O-146 was the best oil in the spark ignition and 2-1/2-ton vehicles; however, it exhibited poor performance in the LDS 465A1 engines in terms of deposition, bearing wear, and possibly bearing corrosion.

  (2) CCL-O-145 was a close second and illustrated the best performance in the LDS 465 engine, making it the best in total performance.

  (3) CCL-O-144 was nearly equal in terms of deposition to 145 and 146, but appeared to cause liner and ring scoring and scuffing.

  (4) CCL-O-147 exhibited significantly poorer performance in almost all categories than the other three oils.

- The use of gasolines having high induction system deposits indices results in significantly dirtier engines.

Gear Oils

- All oils performed generally satisfactorily although a slight compatibility problem was demonstrated with the axles in the jeep vehicles.

- CCL-G-148 was the poorest performer causing rust deposits and seeming more prone to scoring.

- Qualification procedures for gear oils do not adequately provide assurance for satisfactory performance over a long time period.

Greases

- All greases performed equally satisfactorily.

Brake Fluids

- Brake fluids VV-B-680 and MIL-H-13910 give satisfactory operational performance but tend to cause corrosion and gum buildup during periods when brakes are not activated. Preservative fluid MIL-P-46046 causes less corrosion and gum and operates efficiently within its temperature limitation.

Antifreeze

- MIL-A-11755 antifreeze will perform adequately in lower-heat-output Military engine systems. Marginal to poor performance can be expected from the antifreeze in higher-heat-output engine systems, when operating in high ambient temperatures.

Spectrometric Oil Analysis

- Analysis of used engine oils by spectrometric techniques can be an effective means of identifying potentially castastrophic failure conditions. However, normal wear rates could not be correlated with measurements of wear metals in the oils.

- Coolant leaks and dust ingestion can be readily detected using spectrometric analysis.

- Other tests used in conjunction with spectrometric analysis provide clearer interpretation of analysis results.

RECOMMENDATIONS

Based on the observations and conclusions drawn from the road test, the following recommendations are made:

- An oil quality performance program should be conducted to improve the performance of present oils so that they may be used in all general purpose vehicles. Also, consideration should be given to include bearing wear requirements as a part of the specification.
- Stringent compatibility requirements should be established, implemented, and maintained for each critical vehicle component.
- An induction system deposit index requirement should be included in the combat gasoline specification.
- Strong considerations should be given to modify the qualification procedure for gear oils to include interim evaluations in order for previously qualified products to remain qualified.
- Controlled fleet tests of this type should be conducted on an annual or semi-annual basis covering a representative range of vehicles and operating conditions.
- A cost analysis survey should be made to determine the applicability of spectrometric oil analysis to selected combat and general purpose vehicles.
- Sintered iron pistons replace aluminum pistons in all brake cylinders in the earliest time-frame. Also, in instances where storage of vehicles containing aluminum pistons is anticipated, operational fluids should be drained and replaced by preservative fluid MIL-P-46046.
- Drain periods recommended in TB 750-651 for MIL-A-11755 antifreeze be followed in order to avoid usage after inhibitor depletion.
- Work be undertaken in developing and subsequent field testing of MIL-A-11755 antifreezes containing improved inhibitors.

DETAILED DISCUSSION OF TEST

TEST MATERIALS

Test materials selected for test consisted of three MIL-L-2104B and one DEF-2101D engine oils, four MIL-L-2105B gear lubricants, one MIL-G-10924A amendment 2 grease and one qualified and two experimental MIL-G-10924B multipurpose greases, three brake fluids (one each meeting specifications VV-B-680, MIL-H-13910, and MIL-P-46046), and one MIL-A-11755 arctic antifreeze. Two MIL-G-3056B gasolines of differing induction systems deposit indices, one MIL-F-45121B (CITE-R) fuel, and a Caterpillar 1-H reference diesel fuel were used. Physical property data for the various engine oils, gear lubricants, greases, brake fluids, and antifreeze are presented in Table 1. Fuel data are given in Table 4. The vehicle-test material-fuel combination used during the test are shown in Table 5.

TEST FLEET

The fleet of twenty general purpose Army vehicles consisted of five M151A1, 1/4-ton trucks; two M37B1, 3/4-ton trucks; five M715, 1-1/4-ton trucks; five M35A2, 2-1/2-ton trucks; and three M54A2, 5-ton trucks. The 1/4 through 1-1/4-ton vehicles were powered by gasoline engines; while the 2-1/2 and 5-ton vehicles were powered by multifuel engines. The test vehicles are described in Table 6 and Appendix I.

INITIAL PREPARATION

Engines

All engines were disassembled for inspection and initial measurements in order to ensure that all parts were in clean, new condition, free of deposits and rust, and that proper fit and clearances prevailed. This provided starting point from which the wearing depositing characteristics of the lubricants could be gauged. All original equipment piston rings and rod bearings were placed with new parts. Ring end gap, ring side clearance, cylinder bore diameters, and rod bearing weights were recorded at the beginning and end of the test to appraise wear. Other dimensions routinely checked initially included such items as piston to cylinder clearances, shaft and camshaft end play, valve guide and stem diameter, injector and ignition timing, etc. In addition, the heads, valves, and ports were cleaned and the valves were refaced and reseated. Preparation of the engines was routine with one notable exception. The M37B1 engines had been rebuilt prior to delivery for this program. In accordance with overhaul depot practices, the engines had been bored and dry sleeved. The number four cylinder in engine serial number US 24-3267 from truck 3G6207 had no contact between the dry liner and the block for approximately 1/2 of the cylinder circumference from the top of the block to a depth of at least 3/8 inch. A new bare block was purchased and, to facilitate assembly of the vehicles at the time, was installed in truck 3B3632. The engine received in 3B3632, also a sleeved engine, was satisfactory and was run in vehicle 3G6207. The engine run in 3G6207 also had a 0.010-in. undersize crankshaft, with 0.010-in. undersize rod and main bearings. The number 3, 4, and 5 rod journals had a slight scuffed appearance but felt smooth. The rod bearings plastigauged 0.0007 to 0.0008 in., which is tighter than desirable but within the tech manual specifications for the fit of new parts. In addition to the rod bearings, main inserts were replaced because the original ones were heavily corrugated and in poor condition. All exhaust valves and intake valve guides were installed new in the block in order to start with the correct valve stem to guide clearances. The new bore block for truck 3B3632 was built up with new rod and main bearings and standard pistons with new rings drawn from Army stock. The cam followers from the Army engine were also used. Six were 0.0008 in. oversize so the corresponding holes in the new block were reamed to the correct size to fit these tappets.

Other exceptions to routine were the replacement of the number one cylinder liner in one M548 engine due to a 1-1/2-in.-long circumferential crack around the top, and the fact that the new rings supplied by Sealed Power for the multifuel engines had apparently been honed somewhat more than those which had come in the engines.

POWER TRAIN

The gear assemblies were removed from the trucks and disassembled to the extent necessary to determine that each was clean, free of rust, in new condition with proper backlash, and had no indication of wear or corrosion. There were several deviations from these conditions and the corrective steps taken are discussed below.

The axle assemblies from all five M151A1 jeeps contained a lubricant which separated into a tan material and a white fraction. A sample of the oil and one of the complete carrier assemblies was forwarded to Aberdeen Proving Ground for their inspection. Tests of the oil indicated the water content was nil. Rust and corrosion were prevalent on the gears and bearings and the lubrited finish on the ring gear teeth appeared coarse and unsuitable for tests. Five new carriers were purchased to equip the rear of each jeep, and the best five remaining original equipment units were selected for the front axle. The five new units were entirely free of rust and the tooth surface finish was much smoother than the original units.

The axle carrier assemblies received in the two 3/4-ton M37B1 trucks were rebuilt units considered unsatisfactory for tests. The units in 3G6207 utilized plain gears. Although the rear axle, ring, and pinion contact pattern was satisfactory, the coast side of the ring gear had 25 percent of each tooth scored. The front axle had a satisfactory contact pattern and no distress, but was not lubrited. The carriers in 3B3632 had very thin lubriting, the rear axle ring gear had a little scuffing at the heel on the drive and coast side, and the pinion had numerous scars and scratches on the drive side. The front unit in this truck had heavy machine marks going through a decidedly toe-heavy drive side contact. All four carriers were replaced with new lubrited L-37 units drawn from Institute stock. The transfer cases and transmissions from both trucks were slightly used but were in good condition. The only replacements necessary were a small bearing and cup at the rear of the lower rear output shaft, and a larger cup at the front of the lower rear output shaft in the transfer cases.

The intermediate axle pinion shaft in the M34A2 truck 4J2695 had approximately 0.010 in. end play; one shim was removed as a correction measure and the contact pattern was judged to be satisfactory after this adjustment.

CHASSIS

All universal joints and constant-velocity joints in all trucks were disassembled, washed, dried, inspected, packed with the test grease specified, and reassembled. Only two U-joints (from jeeps) were rejected as unsatisfactory for test and replaced. The 2-1/2-ton trucks had the newer (drive line type) U-joints in the front wheel constant-velocity joints.

All of the wheels were removed from the trucks and the wheel bearings and hubs were washed with solvent, dried, and inspected. Wheel bearings were considered satisfactory for test if they appeared essentially new with hone marks still on the contact face of the cups and no pits or evidence of corrosion or brinelling. Bearings not meeting these criteria were replaced. There was a prevalence of brinelled cups on the front wheel inner bearings and new inner wheel bearing cups were installed on both front wheels of both M37B1 trucks and on all five of the M35A2 trucks. The brinell indentations were not severe but could be felt with a fingernail and existed on only part of the periphery of each cup, suggesting that this was caused by vibration during shipment.

The bearings were thoroughly packed and some surplus grease allowed to remain on the outside of each roller-cone assembly. The interior of each hub was covered with a thickness of about 1/4 to 3/8 in. of grease and the spindle was thinly coated with grease to minimize rusting and fretting corrosion. New seals were installed as required and new corks were positioned in the keyway slots on the spindles.

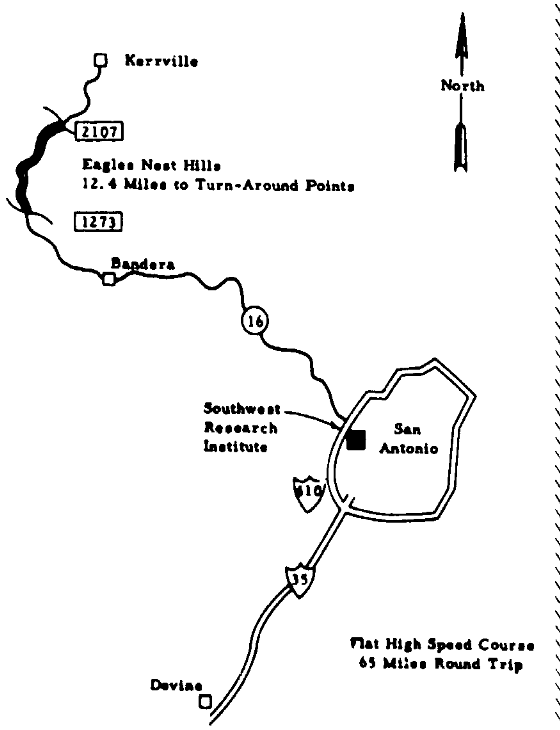
While the wheels were off, new brake cylinder assemblies were installed. These had been previously prepared using complete new cylinders drawn from Army stock. The new cylinders had been disassembled,

washed with ethyl alcohol, and the parts inspected for any evidence of scoring, corrosion or discoloration. The durometer hardness of the cups was measured 1/4 in. from the center of each cup at four points, 45 deg apart, with a Shore Type A-2 durometer as specified in ASTM Method D676-59T. The inside of the cylinder was coated with the assigned test brake fluid and, after dipping the pistons and cups in this fluid, the cylinders were reassembled. The cylinders were numbered with the numerals right-side-up as the cylinder is installed on the backing plate. This orientated the left and right cups. New master cylinders were treated similarly, installed in the chassis, and filled. The brakes were applied numerous times to flush out residual fluid in the system, and the master cylinder was refilled several times. The brakelines were then connected to the wheel cylinders and the system was filled and bled in the usual manner.

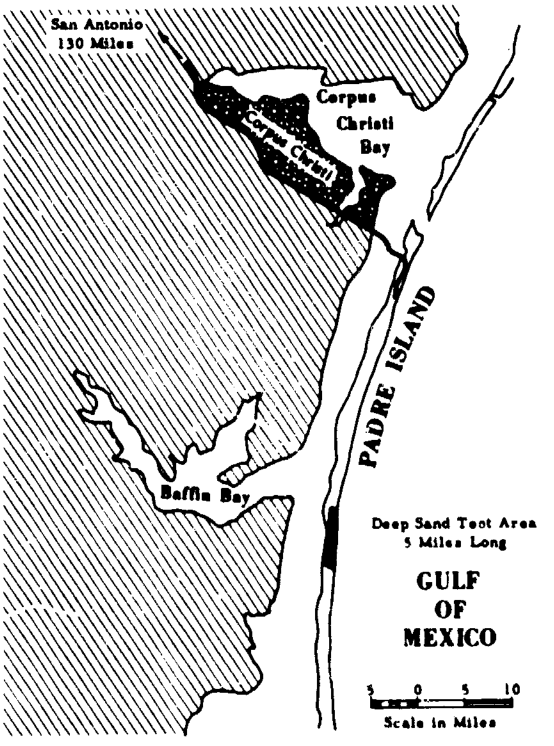
TEST COURSE

Two highway courses were used during this program. The Institute can be visualized as being located at the 9 o'clock position immediately inside Loop 410, an interstate highway which circles San Antonio. The flat road, high-speed operation was run counterclockwise along Loop 410 around to the 7 o'clock position, and from there southwest along Interstate 35 to Devine. This route is comprised entirely of divided highway with minimum grades and the route is lightly traveled so there was no interference from traffic. Only one stop was required every 32.5 miles at the turn-around points, and, during each 8-hr shift, the drivers made four round trips between Devine and the intersection of Loop 410 and Culebra Road, to accumulate 271 miles. The turn-arounds at both ends of this course were made by turning onto the frontal road and stopping at the intersection stop sign. Two left turns were made under the highway bridge and the truck was driven back onto the divided highway, in the opposite direction.

The second highway course was along Loop 410 clockwise to the 10 o'clock position and then northwest on State Highway 16, through Helotes, Pipe Creek, Bandera, and Medina to an areas with steep hills (identified as Eagles Nest), near the turn-around point 72 miles from the Institute. All of route 16 is characterized by numerous hills and turns as the road crosses the rolling terrain and low mountains along the Balcones fault. The Eagles Nest area has 15-percent grades, and the drivers doubled back and forth over



HIGHWAY TEST COURSES



DEEP SAND TEST AREA

these grades between north and south turn-around points 12.4 miles apart at the intersections of route 16 with farm roads 1273 and 2107, respectively. The gasoline-powered vehicles could make ten passes (five round trips between the turn-around points) over these hills and return to the Institute at the end of the shift, accumulating 250 miles (including mileage at the end of the shift associated with coming in the Institute back entrance). The larger trucks could complete six passes over the Eagles Nest hills for a total of 200.4 miles per shift. The hill course provided strenuous high-torque operation of the gear train since it required use of low transfer gears and first and second gear in the transmission.

Appropriate safe speeds of operation, commensurate with previous tests of this type, were specified in the driver's instructions. These were:

Jeeps	50 mph
3/4 and 1-1/4-Ton	45 mph
2-1/2-Ton	40 to 45 mph
5-Ton	40 to 43 mph

In addition to the 19,600 miles each truck was scheduled to run on the highway, 400 miles were driven in the sand at Padre Island (approximately 160 miles southesast of San Antonio) south of the causeway near Corpus Christi, Texas. The first 3 days of sand operation were run in the dry blow-sand at the back of the beach and on some adjacent dunes. Much of the island was still wet and swampy from the deluge of hurricane Beulah which had passed only a short time earlier. The latter part of the first 200 miles was run in an area known as "Little Shell" on federal property 25 miles south of the causeway posted for four-wheel drive vehicles only. This is an area with very soft sand and the truck wheels sink, requiring continuous use of lower gears. During the first 200 miles of operation on Padre Island, the trucks carried their cross-country rated payload and no towed load. The gasoline-powered vehicles were much more mobile than the 6 X 6's, so, during the second 200 miles, it was decided that all of the gasoline-powered trucks would pull their trailers, ballasted to the cross-country rated load.

INSTRUMENTATION

Test parameters to be monitored included road speed, mileage, time, and temperatures. The first three items were recorded on Sangamo tachographs. Temperatures were obtained from thermocouples installed in the sumps of each axle, the transmission, transfer case and engine, plus engine-water-out, engine oil gallery, fuel to and from the engine (multifuel only) and inside a front and a rear wheel brake cylinder (the latter on only one of each model truck). A lead was provided to connect to the thermocouples installed in the front wheel hubs of each truck to measure the temperature of the outer bearing outer races immediately after the truck was stopped. All leads to the thermocouples were 23 ft long to give equal resistance to any point so the driver could observe these temperatures on a pyrometer and multipoint selector switch installation in the cab. Temperatures were obtained by the following three methods:

(1) Each truck was equipped with a pyrometer and multipoint thermocouple switch so that temperatures could be logged by the driver at specified points along the route.

(2) A continual temperature log over each type of terrain was obtained at least once on each type of vehicle at 2 to 5-mile intervals by an observer using a Leeds and Northrup potentiometer.

(3) Continual temperature records were obtained with a 12-point Leeds and Northrup recorder during the latter stages of the test. Points were recorded at 1/3-mile intervals.

Voluminous temperature data were obtained during the test and are summarized by the tables in Appendix III. Also, the figures in Appendix III summarize the temperature data taken by observers with the Leeds and Northrup potentiometer during the high-speed portion of the test, and at ambient temperatures of 80° to 90°F.

In addition to the parameters previously described, exhaust emissions were determined after a reasonable break-in period and at the conclusion of the test. CO and CO_2 were measured on the gasoline powered trucks and smoke readings were taken from the multifuel engines. The gasoline emissions were measured with Beckman nondispersive infrared equipment, and smoke levels were measured with the U.S. Public Health Service Smoke Meter. Data and results from this investigation are tabulated in a separate appendix report but may be summarized with the statement that no significant changes occurred between the beginning and end of test.

MAINTENANCE

Scheduled maintenance was essentially that called for in the tech manual for each vehicle but, specifically of interest to this test, included greasing of chassis components at 1,000-mile intervals, and engine oil and filter changes at 6,000-mile intervals. However, in actuality, the filter changes occurred at 5,800 and 12,000 miles with no oil change during the final 8,000 miles of test.

Unscheduled maintenance in some instances comprised a significant portion of the test effort and a summary of this provides an insight into the operation of each individual vehicle. Therefore, a detailed account of the unscheduled maintenance on each vehicle is presented in Appendix IV and a summary of the problems encountered with each vehicle is presented below.

The M151A jeeps ran reliably and required relatively few repairs. Frequent or recurrent problems reflecting vehicle deficiencies included: (1) the ignition coil vibrates loose in the watertight distributor housing causing the resistor under it to short out; (2) the seal on the engine oil dipstick is not securely attached and both the seal and little cap above it were inclined to come off the stick and get lost; (3) the tubular exhaust manifold works its way backward about 1/4 in. and can possibly cause some increase in exhaust backpressure.

The most prevalent problem experienced with the M37B1 truck occurred with the flexible lines which lead to the oil filter. Those supplied with the engines had apparently deteriorated on the inside and use of higher quality lines is recommended. In addition, the overhaul gasket kits had thin paper gaskets for the pressed steel timing cover which did not seal well.

Like the jeeps, the five M715 trucks ran well and required relatively few repairs. Some problems were experienced in truck 3F3183 including fan belts thrown off, broken harmonic balancer, broken flywheel bolts, and broken timing chain guide. However, an opinion was expressed by the inspection team that the series of problems which had occurred were probably all due to an overreved condition. It should be noted that these trucks did not have engine speed governors. It is understood that more recent production models include this feature as well as new air cleaners and cowl ventilations for the cab.

The 6 X 6 M35A2 trucks also required relatively few repairs and most were random failures rather than recurrent trouble. The most significant failure was a broken crankshaft in truck 4J2695 at 11,480 miles, illustrated by the photograph in Figure 1. The failure occurred while the truck was being driven on flat road at approximately 40 mph with normal temperatures and coolant levels. Several of the inspection team members attributed this failure to a metallurgical fault in the shaft and considered it an isolated failure not necessarily indicative of an engine deficiency. Recurrent problems were experienced with the large three-relay voltage regulators either failing to charge enough or overcharging. These units, however, can be cleaned and readjusted easily without removal from the truck, but solid state regulators might be more reliable. In addition, the M105 trailers towed behind the 2-1/2-ton trucks used the same six-lug wheels as those on the truck. This wheel does not have any pilot in the center on the trailer hub and all radial loads are carried by the studs, which seems to contribute to a proneness to breaking these studs.

The three M54A2 5-ton trucks required the largest number of unscheduled repairs. Most of the trouble centered around the engine, clutch, and electrical system. The engine deficiencies will be discussed more fully in the section of the report covering the engine oil test results. The clutches in all three trucks

failed with mileages between 7,286 and 12,726. Recurrent failures were experienced with the starter solenoid and the turn and brake signal light junction box on the firewall under the hood in front of the driver.

ENGINE OIL TEST RESULTS

As previously discussed, four engine oils were investigated, three qualified MIL-L-2104B products (CCL-O-144, 145, and 146) and one meeting specification DEF 2101D (CCL-O-147). The gasoline used in the spark ignition engined vehicles met specification MIL-G-3056B and had the properties illustrated in Table 4. Two fuel blends were utilized which met all the specification requirements However, one of these termed a clean fuel gave low intake system deposits (ISD) whereas the other, although having a low ASTM gum value, gave high deposits in the ISD test and was termed a dirty fuel. One 1/4-ton M151 and one 1-1/4-ton M715 operated on this dirty fuel and developed excessive deposits on the intake valve tulips, in the intake valve ports as illustrated in the photographs in Figures 2 and 3, and generally resulted in a dirtier engine than with the same oil and the clean fuel. The use of this fuel clearly demonstrates the desirability of including an ISD index number in the military gasoline specifications. The compression ignition engined vehicles operated on fuels meeting the MIL-F-45121B specification (also included in Table 4) for the first 12,000 miles and on a Cat 1-H diesel fuel for the final 8,000 miles, with properties also shown in Table 4. A tabulation of the engine, vehicle, lubricant, and fuel combination as well as a summary of the inspection observations on each vehicle is shown in Table 7. The arbitrary 1 to 5 rating scale is used in summarizing the condition of each part listed with 1 = clean. In order to present a more comprehensive picture of the performance of the lubricant, each series of vehicles will be discussed individually.

1/4-Ton M151 Jeeps—All five engines from the 1/4-ton trucks were generally clean and wear was very low. An index of the overall cleanliness of these engines can be gauged from inspection of the photographs in Figures 4 and 5. Two pistons, the rocker cover, timing gear cover, and oil pump screen are shown from vehicles 2J8600, and 2J8666, respectively. Vehicle 2J8600 was run on the dirty fuel and CCL-O-145 oil and represented the most severe case, whereas vehicle 2J8666 run with clean fuel and CCL-O-144 oil represented the mildest in terms of cleanliness. All five engines maintained good compression without any valve burning, although one unusual characteristic noted was a proneness towards scoring of the rocker arm shaft inside the support posts. However, this was not detrimental to the operation of the engine. Rod and main bearings were generally smooth, free of pits, and fully serviceable. Wear and performance data are shown in the table below and, as may be seen from the table, no excessive wear was observed. In addition, the performance of the vehicles with respect to fuel and oil consumption was quite acceptable. In terms of specific ranking of the oils, the combination of CCL-O-145 and the dirty fuel resulted in the poorest performance in almost all categories. With the clean fuel, CCL-O-147 was significantly poor in almost all categories and overall ranking was almost equivalent to the performance of CCL-O-145 with the dirty fuel. The remaining three oils with the clean fuel performed very nearly the same. However, light scuffing of the liners was noted with CCL-O-144 and not with 145 and 146. Valve train deposits were essentially the same with 144 and 146 and slightly higher with 145, whereas CCL-O-146 had the best rings, and the use of 144 resulted in some light scuffing and scratching. All engines had light scuffing and wear on the rocker shafts and none of the oils exhibited a sludging problem in this series of engines. To recap then, the performance of CCL-O-144, 145, and 146 was nearly equivalent, whereas that of 147 was significantly poorer than the other three oils. The performance of CCL-O-145 with the dirty fuel was essentially the same as that of CCL-O-147 with the clean fuel. No compatibility problem between the engine and oils was apparent.

3/4-Ton M37B1 Trucks—The engines in the M37B1 vehicles have a long-established compatibility with MIL-L-2104B lubricants. Both engines used in the program were rebuilt and, because of mechanical failures and other problems described in the appendix under unsheeduled maintenance, the evaluation of the oils in these vehicles was considered essentially inconclusive. Both engines evidenced low deposit levels consistent with that observed in the jeeps and the vehicle run with CCL-O-146 oil was observably cleaner than that run with CCL-O-144 oil. The oil pan, crankshaft, and lower end of the 3B3632 engine were found to be rusty during the final inspection, but this condition did not prevail when it was disassembled. The test

AVERAGE WEAR AND PERFORMANCE, M151 JEEPS

Truck No. Oil CCL-O-	2J8600* 145	2J8645 146	2J8666 144	2J8669 147	2J8693 145
Top Ring End Gap Increase, in.	0.010	0.025	0.009	0.007	0.009
2nd Ring End Gap Increase, in.	0.014	0.012	0.012	0.008	0.012
3rd Ring End Gap Increase, in.	0.019	0.033	0.013	0.021	0.021
4th Ring End Gap Increase, in.	0.018	0.032	0.014	0.022	0.022
Whole Rod Bearing Weight Loss, g	0.0785	0.1650	0.0740	0.0857	0.1247
Fuel, mi/gal Flat Road Hilly Road	 15.72 15.05	 15.95 14.65	 15.27 14.39	 15.89 14.92	 14.61 14.19
Oil Consumption, lb 0 to 5,800 mi 5,800 to 12,000 mi 12,000 to 20,000 mi	 3.76 1.40 2.41	 2.56 4.27 6.24	 1.88 3.98 3.16	 1.87 2.51 4.72	 2.98 4.63 4.45
Cylinder bore wear was of the order of 0.0001 to 0.0006 in. in all engines.					

*2J8600 used "dirty" fuel, all others, "clean" fuel.

was terminated on this truck after 19,058 miles when the No. 3 rod bearing failed. The oil was drained, pan removed, and bearings inspected. The pan was reinstalled and held in place with several bolts and the truck set aside for 2 weeks before the engine was removed and disassembled. It was during this interval that rust developed. From the data in the following table, ring wear in the 3B3632 engine was normal and consistent with previous tests on this model truck. End gap increase of the No. 2 rings was actually less than is usual since previous programs have shown that a 0.060-in. increase in the end gaps of the No. 3 and No. 4 rings is not unusual. Oil consumption was higher in the 3G6207 engine and is probably in part explained by the greater increase in the ring end gaps. Cylinder bore wear was considered reasonable in both engines considering the test conditions and the greater cylinder and oil ring wear evidenced in engine 3G6207 was probably a result of this engine's having been bored and sleeved prior to delivery. To summarize, the mechanical problems experienced by these engines was not concluded to be a compatibility problem between the engine and lubricants due to the long established compatibility with MIL-L-2104B oils, and the performance of CCL-O-146 was superior to that of CCL-O-144.

1-1/4-Ton M715 Trucks–The final inspection of engines from the M715 trucks produced no evidence of compatibility problems with the lubricants tested. As a group, the engines were dirtier than those in the jeeps and more separation in the performance of the four oils was apparent. As with jeeps, the engines and oil combination run with the dirty fuel had considerably heavier varnish and sludge deposits throughout than the same engine run with the same oil and clean fuel, as illustrated in Figures 6 and 7.

AVERAGE WEAR AND PERFORMANCE, M37B1 TRUCKS

Truck No. Oil CCL-O-	3B3632 146	3G6207 144
Top Ring End Gap Increase, in.	0.028	0.015
2nd Ring End Gap Increase, in.	0.010	0.045
3rd Ring End Gap Increase, in.	0.054	0.099
4th Ring End Gap Increase, in.	0.048	0.098
Whole Rod Bearing Weight Loss, g	*	0.1665†
Cylinder Bore Wear Transverse Longitudinal	 0.0007 0.0001	 0.0017 0.0021
Fuel, mi/gal Flat Road Hilly Road	 8.28 7.80	 8.12 7.81
Oil Consumption, lb 0 to 5,800 mi 5,800 to 12,000 mi 12,000 to 20,000 mi	 31.27‡ 19.07 19.41	 11.86 20.82** 44.69††

*Test terminated with a rod bearing failure at 19,030 mi. The rod bearings were in too poor condition for the weight loss to relate to evaluation of the lubricant.
†Weight loss for 10,184 mi.
‡Truck had several leaks resulting in high oil consumption.
**Defective vacuum pump caused high oil consumption.
††Several leaks accounted for part of this high oil consumption.

Engine 3F3183 was run with CCL-O-144 and the clean fuel, whereas 3F3175 ran with the same oil and dirty fuel. One interesting note is that the difference in the influence of the fuel was more apparent in these engines than in the jeeps where the clean and dirty fuels were paired with CCL-O-145 oils. In both engines, however, the dirty fuel developed excessive intake valve and port deposits. The photographs in Figures 8, 9, and 10 complete the comparison of the deposit forming proclivities of the test oils. CCL-O-147 is again significantly poorer than the remaining three oils, whereas, visually there is little to choose among 144, 145, and 146. From the inspection data, it is interesting to note that CCL-O-146 was rated the cleanest of the remaining three oils with CCL-O-145 a very close second. Also of interest is the fact that, as in the previous engines, light scratching or scuffing occurred in the bores of the engines using the CCL-O-144 oil. Wear and performance data are illustrated in the following table. Wear was very low throughout all five engines and the magnitude of wear of comparable parts was similar. Rod and main bearings were generally smooth, free of pits, and, with the possible exception of one main bearing in 3F3183, were judged serviceable for considerable additional mileage. Cylinder bore wear was nil and ring wear was low. Compression on all cylinders was good and no valves were burned at any time during the test. Oil consumption seemed higher than might be expected from an engine of this size but no leakage problems occurred and varying degrees of

blue smoke in the exhaust, especially at idle, were investigated several times during the program. All the valves and all seals on the stems were in good pliable condition and in their proper position. The overhead cam valve deck was noted to run unusually wet, and it may have been a contributing factor. Three top rings in each of two engines, 3F3175 and 3F3183 run with CCL-O-144, were partially cold-stuck but, when the engine ran, these rings were free enough to make full contact and perform normally. All rings in the M715 except that run with CCL-O-145 were characterized as sluggish. One other unusual feature is the stop cut on the outer periphery of the No. 2 rings which face up. Usual practice is for an outer periphery step cut to face down and inner periphery step cuts or chamfers to face up.

AVERAGE WEAR AND PERFORMANCE, M715 TRUCKS

Truck No. Oil CCL-O-	3F3072 147	3F3078 146	3F3175 144*	3F3183 144	3F3199 145
Top Ring End Gap Increase, in.	0.010	0.007	0.008	0.021	0.007
2nd Ring End Gap Gap Increase, in.	0.005	0.007	0.004	0.006	0.007
3rd Ring End Gap Gap Increase, in.	0.010	0.013	0.010	0.017	0.008
Whole Rod Bearing Weight Loss, g	0.0588	0.0772	0.0812	0.0782	0.0666
Cylinder bore wear was of the order of zero to 0.0006 in. in all endings.					
Fuel, mi/gal Flat Road Hilly Road	 9.33 8.48	 9.39 8.45	 8.92 8.42	 9.25 8.60	 8.89 8.05
Oil Consumption, lb 0 to 5800 mi 5,800 to 12,000 mi 12,000 to 20,000 mi	 18.06 19.32 28.55	 27.26 18.50 31.96	 16.86 18.79 21.44	 14.51 13.53 21.55	 24.95 27.13 32.31
*3F3175 used "dirty" fuel, all others used "clean" fuel.					

To summarize the oil results in this engine, there was again a significant difference in the performance of engines with and without the dirty fuel. The magnitude of difference with the CCL-O-144 oil was greater than that encountered previously in the jeeps with the CCL-O-145 oil. However, drawing a conclusion from this could be misleading since engine parameters are also involved. Among the four test oils, CCL-O-147 was significantly poorer in performance than the remaining three with CCL-O-146 appearing to be slightly superior. Light scuffing and scratching in cylinder bores were again noted with CCL-O-144. However, no problems were considered to be highly significant, and it was concluded that the engines from the M715 trucks exhibited no compatibility problems with the lubricants.

2-1/2-Ton M35A2 Trucks–The LDS-465-1 engines which are the naturally aspirated version of the 478-cu in., 22.5:1 compression ratio, multifuel series powering the 2-1/2-ton trucks performed satisfactorily throughout the duration of the test. Durability was satisfactory with all four engines maintaining compression without trouble or burning of any valve. The wear and performance data illustrated in the following table indicate no apparent difference between the oils on the basis of the wear data. None of the injectors or injector pumps required replacement during the test although the opening pressures had

AVERAGE WEAR AND PERFORMANCE, M35A2 TRUCKS

Truck No. Oil CCL-O-	4J2578 146	4J2594 147	4J2695 147	4J4609 144	4J4623 145
Top Ring End Gap Increase, in.	0.003	0.002	0.003	0.002	0.003
2nd Ring End Gap Increase, in.	0.003	0.002	0.003	0.002	0.002
3rd Ring End Gap Increase, in.	0.005	0.004	0.004	0.005	0.004
4th Ring End Gap Increase, in.	0.007	0.007	0.005	0.008	0.004
Whole Rod Bearing Weight Loss, g	0.1185	0.1294	0.1249	0.1071	0.0839
Cylinder bore wear was of the order of 0.0004 to 0.0009 in. in all five trucks.					
Fuel, mi/gal Flat Road Hilly Road	 7.08 6.60	 7.21 6.84	 7.28 7.00	 7.02 6.62	 7.14 6.86
Oil Consumption, lb 0 to 5,800 mi 5,800 to 12,000 mi 12,000 to 20,000 mi	 21.02 28.25 30.99	 16.89 19.61 31.89	 25.77 40.15 40.86	 11.57 22.45 9.24	 29.33 29.45 25.93

dropped to the 2050 to 2200-psi range from a normal value of 2600 psi. Four of the 30 injectors had developed opening pressures below 2000 psi, three of which were in the rear head of 4J4623. Spray patterns were satisfactory from 28 injectors and 22 rated as still chattering. In terms of oil rating, the engine in 4J2578, run with the CCL-O-146 oil, was the cleanest in the group but only marginally better than vehicles 4J4609 and 4J4023 with CCL-O-144 and 145, respectively. Again, however, light scuffing was noted with the CCL-O-144 oil. The two other engines run with CCL-O-147 looked identical with a thin soft black sludge film on many parts and more varnish on the pistons resulting in a lower rating in overall cleanliness. The range of deposition occurring in the engine is illustrated by the piston and valve photographs with CCL-O-146 and 147 in Figures 11 and 12, respectively, and by comparing the various covers of engines run with CCL-O-146 and 147 in Figure 13. Critical rubbing areas such as valve contact faces and seats, piston ring contact faces, and crankshaft journals were generally in very good condition. Varying degrees of scratching occurred among the rod and main bearings and an overall appraisal of the inserts was that they were in a reasonable condition but not as satisfactory as those in the jeeps and M715's. A comparison of bearings from engines run with CCL-O-146 and 147 is shown in Figures 14 and 15, respectively. The light scratching on the main bearings is evident and of approximately the same magnitude for each of the two oils. However, the distress noted on the rod bearings is significantly greater with CCL-O-147 leading to the conclusion that the bearings would probably be an early point of distress for a less compatible lubricant.

5-Ton M54A2 Trucks—The LDS-465-1A engines are the turbocharged version of the 478-cu in. displacement, multifuel engine used in the 2-1/2-ton M34A2, and those involved in this program were built prior to the introduction of the derating modifications. In addition to the turbocharger, major items included in the LDS version are different pistons with an oil cooling annulus, changes in the delivery rate of

the injector pump, different injectors, flywheel and flywheel housing, clutch, and inclusion of a power steering pump on the front timing gear cover. Only one of the three 5-ton trucks (5E5776 with CCL-O-145 oil) completed 20,000 miles. Unit 5E5774 (CCL-O-147) fell behind in mileage accumulation because of repairs and was terminated though still running after 17,451 miles in order to meet the final inspection schedule. Truck 5E5775 with CCL-O-146 was terminated after 14,073 with a cracked block. The relative longevity of each engine, however, was not considered dependent upon which of the three oils was used. A total review of the excessive mechanical repairs the three engines required is in Appendix IV under unscheduled maintenance. However, the conditions found during final inspection can be summarized by the statement that these engines seemed to have been thermally and mechanically overstressed, that an incompatibility with the lubricants was apparent, and that the engines would benefit from an improvement program. General areas of distress included:

(1) Scuffing of cylinder bores and scoring of the three top rings and the piston skirts. Photographs illustrating this ring scuffing for CCL-O-145, 146, and 147 are presented in Figures 16, 17, and 18, respectively. It is of interest to note that CCL-O-145 had superior performance in this particular regard and in the LDS engines in general.

(2) Heavy wear on the rod and main bearings (one rod bearing failed in 5E5775 at 7,286 miles). Sets of rod and main bearings are illustrated in Figures 19 and 20 for CCL-O-147 and 145. The high wear is evident as is also the superior performance of the CCL-O-145 compared to 147. The bearings from 5E5775 at 7,286 miles with CCL-O-146 are illustrated in Figure 21. Following this failure, the bearings were replaced and the condition of these bearings at the end of 14,073 miles when the test was terminated due to a cracked block is illustrated in Figure 22. As shown, there was considerable distress making one wonder whether this particular engine-oil combination could survive for 20,000 miles. This tends to confirm the observations of the 2-1/2-ton truck that the bearing area is a critical point. It also points out that in the more highly stressed engine a compatibility problem definitely exists.

(3) Heavy wear and extrusion of the valve contact faces and the valve seats. This condition, in which some valves were actually pushed into the ports, is illustrated by the photographs of valves in Figure 23 and of the rear head of truck 5E5774 in Figure 24. This problem has no bearing on oil performance.

(4) High wear in the valve guides.

(5) Cracked heads between the intake and exhaust valve seats. This problem was more disconcerting than harmful since no coolant leaks occurred through these cracks. By closely examining Figure 24, light crack lines can be observed on both end cylinders.

(6) Loosening of the valve seat inserts in the heads.

(7) Large cracks in the crown of the pistons radiating out from the precup. This condition is illustrated by the photographs in Figure 25. When the cracks are light, there is evidently no performance penalty; however, erosion occurred in this area, and one piston shown in Figure 26 developed a crack through to the oil cooling annulus causing almost complete loss of compression.

(8) One water-air (intercooler) manifold cracked internally allowing coolant to flow into the cylinders locking the engine hydraulically.

(9) One block and cylinder liner cracked allowing coolant to flow into the cylinder and crankcase.

(10) The front crankshaft pulley which supports the harmonic balancer broke twice on one truck.

The fuel injection pumps from the three engines were returned to the manufacturer at the conclusion of the test for inspection of fuel delivery rate measurement. The unit from 5E5776 had a delivery rate of 4.5 percent below specifications at rated speed with DF-2 diesel fuel. There were indications that the density compensators did not provide the 10-percent additional delivery which is normal when operating on CITE fuels. These findings seem consistent with the better fuel economy this truck delivered and the conditions of the pistons with less cracking. Steps taken since the manufacture of these engines toward derating and reduction of fuel delivery with the Code 2 pumps appears to be in the right direction and will probably help relieve many of the problems with this engine.

The average wear and performance data illustrated in the table below provide little comparison among the three oils due to the high incidence of mechanical problems. The CRC inspection committee considered all three engines to be relatively dirty with excessive lacquer deposits, partial carbon filling in the ring grooves, and some sludging. The overall spread of cleanliness ratings was rather small, but the CCL-O-145 and 146 oils were judged superior to 147 (in terms of deposits), with 145 appearing to provide the best protection for the engine. Several pistons were sawed open to inspect the oil cooling annulus since there was concern that extended mileage might result in its becoming plugged. Photographs showing these sections of pistons are illustrated in Figure 27 along with a cracked cylinder liner. Although several pistons

AVERAGE WEAR AND PERFORMANCE, M54A2 TRUCKS

Truck No. Oil, CCL-O-	5E5774 147	5E5775 146	5E5776 145
Top Ring End Gap Increase, in.	0.002	0.004	0.002
2nd Ring End Gap Increase, in.	0.002	0.0015	0.001
3rd Ring End Gap Increase, in.	0.004	0.005	0.002
4th Ring End Gap Increase, in.	0.004	0.009	0.004
Whole Rod Bearing Weight Loss, g	0.4776	1.6918*	0.1733
Average Cyl Bore Wear	0.0012	0.0023	0.0007
Fuel, mi/gal Flat Road Hilly Road	 4.30 3.81	 4.27 3.84	 4.62 4.08
Pounds of Oil Added Between Changes 0 to 5,800 mi 5,800 to 12,000 mi 12,000 to End of Test	 27.40 (15 qt) 42.22 (23 qt) 41.52 (23 qt)	 34.83 (19 qt) 109.35 (60 qt) engine failed	 26.71 (14.7 qt) 32.38 (18 qt) 25.00 (13.7 qt)
Total Test Miles	17,451	14,073	20,000

*Weight loss for 6,787 miles.

were sawed open, only one was found to have deposits partially blocking the flow of oil. Comparison of the parts from the high mileage engines with CCL-O-147 and 145 are shown in Figures 28, 29, and 30. Typical piston and valve photographs in Figures 28 and 29 illustrate that the CCL-O-145 was superior as far as piston deposits were concerned. Color photographs of the covers in Figure 30, however, illustrate that CCL-O-145 was only marginally superior to 147.

To briefly summarize the results from the engine oil observations, there is no evidence of compatibility problem with any of the oils tested in the spark ignition and LD-465-1 engines. However, a compatibility problem does exist with the LDS-465-A1 engine. In terms of performance, CCL-O-147 was significantly poorer in all vehicles and use of a high induction system deposit index gasoline significantly increases deposition. In the spark ignition and lightly loaded LDS-465-1, CCL-O-146 was marginally superior in terms of deposits and piston and liner scuffing to the CCL-O-144 and 145 oils. CCL-O-144 and 145 were approximately the same as far as deposits were concerned but CCL-O-144 exhibited scuffing tendencies in all engines. In the more heavily loaded LDS-465 engine, CCL-O-145 was the best performer although none of the oils performed very well.

GEAR LUBRICANT RESULTS

The four gear lubricants evaluated in the test were described in Table 1 and were comprised of three qualified MIL-L-2105B products (CCL-G-148, 149, and 150) and a 50-50-percent blend of 149 and 150 (CCL-G-151). All gear assemblies were inspected prior to and at the conclusion of the test with interim inspections after the first 4,000 miles of high-speed operation and again at 6,400 miles after the first high-torque cycle and 200 miles across the sand. The interim and final inspections were performed by members of the AMC Gear Oil Review Committee, and their findings for the various vehicle components are described below.

Axles

The axles in the 1/4-ton M151 jeeps illustrated a definite need for lubricants having superior antiscore and load carrying capacities than the MIL-L-2105B materials evaluated. Eight of the nine axles which completed the test experienced scoring or ridging on the ring and pinion gear tooth contact surfaces. The rating for each axle is illustrated in Table 8, and typical examples of the distress are illustrated by the photographs in Figures 31 and 32. Photographs of the ring gears and pinions from the remaining vehicles are contained in Appendix V. Although the tooth distress was not severe and all nine axles were operating freely at the completion of the test, this condition is undesirable since gears are case hardened and scoring of the type illustrated tends to destroy the case which then leads to rapid gear tooth wear. The jeeps received at the start of the program were new and the original equipment axle assemblies were found during the preliminary inspections to have rusty bearings and gears. In addition, the lubrite finish on the gears was coarse and porous and the lubricants separated into tan and white fractions. Laboratory analysis indicated water content was nil. Five new carrier assemblies were purchased for use on the rear of each jeep and had tooth surface finishes much smoother than the original equipment units. The five best original units were selected for use in the front position of the jeeps. The distress noted during the final inspection was apparent on all units during the interim inspection though to a lesser degree. The review team was critical of the lubrite finish on the front units and recommended further investigation of the lubricant requirements.

The two 3/4-ton M37B1 trucks were rebuilt units as received for the test; the carrier assemblies had poor contact patterns, and all units were not lubrited. Therefore, all four of the carriers were replaced with new lubrited pedigreed L-37 carriers drawn from Institute stock. The front carriers completed the test without distress. The rear carriers in truck 3G6207, run with CCL-G-150 oil, had only light scratches on both sides of both gears. The unit appeared to have incipient distress early in the test which did not develop further. No problem of any kind was exhibited in the rear carriers of 3B3632 (CCL-G-148) up to 6,400 miles. At the conclusion of the test, however, the drive side of the ring and pinion had developed a combination of scoring and light ridging on 100 percent of the contact area. In addition, soft black sludge deposits covered most of the noncontact areas and thin coking

was present on the noncontact areas of the pinion. Typical photographs from this vehicle are illustrated in Figures 33 and 34.

The 1-1/4-ton M715 axle completed the test in very satisfactory condition with essentially no distress on the gear teeth. Traces of scratching were found on several units and wear was no more than light on any assembly. Deposit levels were also low in all of these axles. The front and rear units in truck 3F3072 (CCL-G-148) experienced very light rusting on noncontact areas predominantly below the oil level, a condition found to be typical with this lubricant. Photographs illustrating the appearance of the gear contact surfaces from a typical rear axle are contained in Appendix V. One axle failure occurred in the M715 trucks at 14,590 miles. The front cover on the front axle of truck 3F3183 either ran into something or was struck by a large rock causing a small dent. The ring gear then rubbed a hole in the cover allowing the oil to run out and ruin the axle. A new axle was installed at this mileage.

The 2-1/2-ton M35A2 double-reduction axle exhibited excellent durability and mild demands on the lubricant. Some scratching was noted on the gear teeth of 7 of the 15 carriers but was described as trace to light in most cases. In addition, the axles were generally clean and free of deposits although the units run with CCL-G-148 had spots of rust in noncontact areas. Photographs of a typical carrier assembly from one of these trucks illustrating their excellent condition is contained in Appendix V. The front axle gear oil in trucks 4J2578, 4J4609, and 4J4623 was found to be contaminated with chassis grease at 20,000 miles, apparently as a result of overgreasing the constant-velocity joints and spindle bearings. The latter two trucks, run with CCL-G-150 and 151, respectively, and both with 234 X 6 chassis grease, developed distress on the coast sides of the upper (hypoid) gear sets, presumably caused by the contamination. Ratings were moderate wear and 60 to 80 percent heavy scoring in the front axle of 4J4609, moderate wear and scoring and ridging on approximately 40 percent in 4J4623. Truck 4J2578 with CCL-G-149 and 233 X 6 chassis grease had much greater contamination in the front axle than the other two trucks but experienced no harm whatsoever. However, it is not known whether this was a matter of compatibility or whether the contamination had prevailed for a shorter time interval. Photographs illustrating the extent of the gear distress described above are shown as Figures 35 and 36.

The double-reduction axles in the 5-ton M54A2 trucks were similar to those in the 2-1/2-ton vehicles illustrating excellent durability and compatibility with the lubricants used in the program. Wear was rated light or very light and the units were clean and very serviceable. Photographs of the rear carrier gears from truck 5E5776 (CCL-G-150, the only 5-ton truck which completed 20,000 miles) are contained in Appendix V and illustrate the typical good condition of these assemblies.

Transmissions, Transfer Cases, and Bearings

The transmission in all 20 trucks and the transfer cases in 16 trucks completed the test without repair. The other 4 transfer cases required only minor repairs while the test was in progress: two for seal leakage and two for speedometer gear slipping. All the gear units were functioning satisfactorily at the end of the test. One lubricant problem was noted with CCL-G-148 which did not adequately inhibit rust and all the gear units with this oil had varying degrees of rust deposits, more below the oil level than above. Figure 37 contains photographs of two jeep transfer cases with CCL-G-148 and CCL-G-149, respectively, and a cover from a M715 axle run with CCL-G-148 (Figure 38) illustrate this condition. The rusting was predominantly on noncontact surfaces. The gear teeth and rolling surfaces of the bearings were in some cases dull looking but were generally serviceable with no evidence of distress. Daily operation of these vehicles was probably responsible for maintaining the clean rubbing surfaces. However, many Army trucks are parked for several months at a time and an inclination toward rusting would be destructive to the contact surfaces. (A sample of the CCL-G-148 oil, which is an approved MIL-L-2105B product, failed the CRC L-33 7-day moisture corrosion test on November 29, 1967 at ALI. As a result, the gear inspection committee considered requiring the 7-day test on all formulations instead of just on new ones.)

During the final inspection, wear was rated as light or very light on all gears, bearings, synchronizers, and shift rails, etc. The orange painted interiors of the cases were generally streaked with a thin coating of black oil which, for the most part, could be wiped with a dry rag, and deposits of sludge or varnish with all

the oils was low. Coking, such as frequently develops on the copper catalyst in the thermal oxidation stability test, was nil. Seventy percent (all five rear and two front) of the main shaft ball bearings in the 2-1/2-ton transmissions developed pitted inner races as illustrated by the photograph in Figure 39. Prevalence of this distress was probably unrelated to the lubricant or brand of bearing and could have been caused by the high levels of vibration existing in this model vehicle. Among the five 2-1/2-ton truck transfer cases, four equipped with BCA No. 1210 bearings supporting the high-speed gear on the input shaft developed broken cages on six bearings, an incidence of 75 percent. The cages broke into numerous small pieces which dropped to the bottom of the case and had no effect on the function of the bearings. The fifth truck had new departure No. 1210 bearings which were in good condition.

Summary of Gear Lubricant Evaluation

All four gear lubricants evaluated exhibited slight incompatibility with the axle in the 1/4-ton M151 jeeps. All axles in this vehicle exhibited some scoring and ridging, and it was not possible to rank the performance of the lubricants in terms of severity. All other vehicles exhibited good compatibility with the series of test oils in both axles and transmissions. Of the four lubricants, CCL-G-148 proved to be prone to rust in every vehicle in which it was used and, in addition, seemed to have greater proclivity toward sludge deposits and scoring, although very light.

GREASES

The four greases evaluated included one MIL-G-10924 amendment 2 and three (one qualified and two experimental) MIL-G-10924B materials. After inspection and cleaning of each bearing, universal, and constant-velocity joint, each unit was packed with the test grease as indicated in Table 1. At the completion of the test, a total of 68 front wheel bearings in trucks and 72 wheel bearings in trailers were examined and the consensus of opinion was that all greases performed equally well and satisfactorily in all bearings. There were three bearing failures, all of a typical spall type which could not be attributed to lubricant failure. The rolling surfaces of the other bearings were in excellent condition in spite of some minor staining that appeared to be caused by an additive in the grease or in some cases from moisture. The sliding surfaces (roller ends and cone large ribs) were polished in the usual manner with indications of little or no wear, and the honing marks were still visible on most bearings.

The inspection of several universal and constant-velocity joints also indicated no deficiencies in lubrication and no differences in the four greases.

One 5-ton truck, 5E5774, had considerable rusting in the hub covers of the wheels. The grease had an emulsified appearance and a sample was taken from the outer bearing of the left front wheel and was found to contain 2.67 percent water. This bearing had water stains on the races and rollers and considerable red color in the grease. The right front wheel of this same truck had the outer bearing rusted to the shaft and required a wheel puller to release it. There was considerable rusting in the hub cover and the grease was heavily contaminated with a red material. When cleaned, the outer bearings showed water stains on the race and rollers and the retainer was rusted slightly; otherwise, it was in good condition. The inner bearing when cleaned had a badly spalled inner race, the rollers were pitted, and the retainer badly rusted. The constant-velocity joint on the right side of the truck also had noticeable rusting clearly showing that a seal had broken, allowing water to get into both front wheels. The right side was in the worst condition.

The fretting damage reported showed no definite distinction between greases and trucks or trailers. There appeared to be somewhat more fretting in the trailer bearings than in the trucks but there was no significant difference. Most of the fretting, indicated as slight, was occasioned by a reddish color in the grease between the inner race and the axle which in most cases was removed by wiping and showed no stain on the metal. That indicated as moderate or heavy showed definite stains or pitting on the metal.

The general conclusion was that the four greases performed equally satisfactorily for the 20,000 miles with no relubrication.

BRAKE FLUIDS

Corrosion was less evident in the brake cylinders containing the preservative MIL-P-46046 than in the cylinders containing the operational fluids VV-B-680 and MIL-H-13910. Several cylinder pistons in vehicles using MIL-H-13910 fluid had become frozen during the interval between end of operation and inspection. Rust buildup in cylinders, due to water pickup-fluid oxidation, was magnified in some cylinders by the galvanic action between iron cylinder walls and aluminum pistons. The laboratory and inspection data on the fluids and cylinders are tabulated in Appendix VI.

ANTIFREEZE

Inspection of vehicle coolant systems showed satisfactory coolant performance in the 1/4, 3/4, and 1-1/4-ton trucks and marginal performance, evidenced by moderate to heavy rusting, in the 2-1/2 and 5-ton trucks. Analysis of used samples of MIL-A-11755 antifreeze indicated a depletion of inhibitors in the higher-heat-output engines resulting in rapid lowering of the pH of the antifreeze and subsequent attack on metal components. Laboratory analysis of the antifreeze from the various trucks are shown in Appendix VI.

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5. Spectrometric Analysis of Used Oils, by L. L. Stavinoha and B. R. Wright, SAE 690776.

TABLES

LIST OF TABLES

TABLE 1. DESCRIPTION OF TEST MATERIALS

Greases - 20-Truck Fleet Test Program

	Code Nos.			
	400*	403	233X6	234X6
Specification	MIL-L-10924A	MIL-L-10924B	Experimental	Experimental
Physical Properties				
Penetration				
Worked		279	275	288
Unworked		259	264	276
Evaporation Loss, Percent		6.38	6.29	6.27
Oil Separation, Percent		3.43	3.56	3.78
Oxidation Stability				
(Pressure drop - 400 hr)		6	6	5
Apparent Viscosity				
Poise at 65°, [illegible] sec^{-1}		18,000	19,200	21,000
100 sec^{-1}		9,200	10,000	11,000
Water Workout, Percent		5.5	5.1	5.3
Wear Characteristics				
4 Ball Wear (Scar dia., mm)		0.62	0.365	0.655
4 Ball EP (Mean Hertz Load)		19.4	40.1	31.3
Falex EP (lb gage load)		750	1000	750
Corrosion Protection		Pass	Pass	Pass
Rust Prevention		Pass	Pass	Pass

Summary of Brake Fluids - 20-Truck Fleet Test Program

Specification	VV-B-680	MIL-H-13910	MIL-P-46046†
Viscosity, cs			
At −67°F	–	706	–
At −40°F	894	–	
At 122°F	6.80	3.54	
At 212°F	2.69	1.60	
Boiling Point, °F	410	313	349
Flash Point, °F	220	165	190
pH			
Initial	10.5	10.7	10.3
Final	10.2	9.2	–

Engine Oils - 20-Truck Fleet Test Program

	Code Nos.			
	CCL-O-144	CCL-O-145	CCL-O-146	CCL-O-147
Specification	MIL-L-2104B	MIL-L-2104B	MIL-L-2104B	DEF-2101D
Reference Oil	–	–	REO-191	NATO
Grade	SAE 30	SAE 30	SAE 30	SAE 30
Physical Properties				
Viscosity, Kinematic, cs				
At 100°F	104.6	129.5	120.1	110.6
At 210°F	11.2	12.6	12.0	10.3
Gravity, API	29.0	19.1	28.0	
Flash Point, °F	455	425	510	
Pour Point, °F	-5	−30	0	
Viscosity Index	101	96	97	78
Sulfated Ash, Percent	0.62	1.03	1.04	
Con Carbon	0.73	1.31	1.08	

Gear Oils - 20-Truck Fleet Test Program

	Code Nos.			
	CCL-G-148	CCL-G-149	CCL-G-150	CCL-G-151‡
Specification	MIL-L-2105B	MIL-L-2105B	MIL-L-2105B	MIL-L-2105B
Reference Oil	RGO-110	–	–	
Grade	SAE 90	SAE 90	SAE 90	SAE 90
Physical Properties				
Viscosity, Kinematics, cs				
At 100°F	207.9	219.2	193.2	
At 210°F	17.4	18.7	17.4	
Viscosity Index	98	102	105	
Gravity, API	24.0	27.0	25.8	
Channeling	0	0	0	
Flash Point, °F	380	360	425	
Pour Point, °F	10	10	15	
Copper Corrosion				
3 hr at 250°F	No**	No**	1	
Insolubles				
Pentane, Percent	Trace	Nil	0.169	

*Data not available.
†Composition 3.
‡A 50/50 mixture of CCL-G-149 and CCL-G-150.
**No blackening.

TABLE 2. SUMMARY OF ENGINE INSPECTION REPORTS

(Taken from Reference No. 2)

Vehicle No.	Oil Code No.	Sludge Rating (Clean = 50 Merits)	Piston Skirt Varnish (Clean = 0 Demerits)	Ring Face†	Piston: Skirt	Piston: Top Land	Cylinder: RTA	Cylinder: BRTA	Bearing: Main	Bearing: Rod	Rod Bearing, Avg wt loss, g	Comments
2J6690*	CCL-O-145	47.1	0.8	Good - Normal (0.017)	Good (lt scratching)	Good - Normal	Fine lines	Normal	Good - Normal	Very lt. scratches	0.0765	No engine problems during test. Poor fuel induction was noted during latter part of test. This engine was using a high ISD gasoline
2J8645	CCL-O-146	47.4	2.0	Good - Normal (0.025)	Fine lines - dirt scratching	Normal	Fine & some coarse lines	Fine & some coarse lines	Normal	Normal	0.1053	Rear axle failed at 19,335 miles and test was terminated. High engine speeds were recorded previous to breakdown
2J6693	CCL-O-145	47.5	0	Normal (0.016)	Fine lines - dirt scratching	Normal	Fine lines	Normal	Normal	Normal - very light scratches	0.1747	No engine repairs during test.
2J8666	CCL-O-144	48.1	0.6	Normal - scuffing on 2nd ring (1) (0.012)	Normal	Few light scratches	Light scratches	Good	Normal	Very light scratches	0.0740	No engine repairs during test.
2J6669	CCL-O-147	47.2	1.8	Normal - light abrasion (1 & 2)(0.014)	Few fine scratches	Normal	Fine lines	Normal	Normal	Normal	0.0857	No engine repairs during test.
3B3632	CCL-O-146	47.0	0	Normal (0.035)	Few fine scratches	Normal	Fine lines	Normal	Fine scratching (overlay wiped on 2)	All wiped - flaked - or corroded		The No. 3 rod bearing failed at 19,058 miles test terminated on.
3G6207	CCL-O-144	28.6/30	6.7	Ring 1 - 2 broken, rest scuffed. Ring 2 - light scuffing. Ring 3 - 1 scuffed Ring 4 - 1 scuffed (0.065)	Few light scratches	Normal	Few light & heavy scratches	Few light & heavy scratches	Overlay pitted	Trace pitting		(1) The No. 1 rod bearing failed at 5,792 miles New rod bearings were installed (2) The No. 1 rod bearing failed at 6,994 miles - New rod bearings were installed. The journal was scored also & a new crankshaft as well as new main bearings were installed. (3) The No. 5 rod bearing failed at 17,178 and scored the crankshaft. The journal was turned undersize and all new rod bearings installed.
3F3183	CCL-O-144	48.3	0.5	Normal (0.015)	Light dirt scratches	Normal	Few very fine scratches	Normal	Fine scratches	Normal (some fine)	0.0782	Bolts holding fly wheel to the crankshaft broke and were replaced at 5,009 miles.
3F3078	CCL-O-146	46.8	0.5	Normal (0.009)	Normal (light scratching)	Normal	Light scratching	Light scratching	Normal	Normal (fine scratching)	0.0772	No engine problems during test.
3F3199	CCL-O-145	48.1	0.6	Normal (0.007)	Normal (few light scratches)	Normal	Few scratches	Few scratches	Normal	Normal (two bottom overlay flaking)	0.0666	No engine repairs were required during the test.
3F3072	CCL-O-147	47.3	4.0	Normal (0.008)	Tr lines	Normal	Fine lines	Fine lines	Good	Good	0.0588	No engine repairs were required during the test.
3F3175*	CCL-O-144	47.4	1.7	Normal (light abrasive scratching) (0.007)	Few fine scratches	Normal	Light scratching	Light scratching	Normal	Normal - one with fine scratches		No engine repairs were required during the test.
4J4609	CCL-O-144	46.0	6.6	Normal (2 broken) (0.006)	Few fine dirt scratches	Normal	Fine lines	Normal	Few fine scratches (Cu showing on 3)	Fine scratching	0.1071	No engine repairs were required during the test.
4J2578	CCL-O-146	47.6	0.3	Normal (one No. 1 broken) (0.005)	Normal	Normal	Tr. lines	Normal	Scratches (copper showing on 3)	Normal	0.1185	Oil sampling valve broke off at 5,989 and was replaced with a loss of 14 quarts of oil (capacity is 22 quarts).
4J2594	CCL-O-147	47.1	2.1	First rings all broken or scuffed, rest normal (0.004)	Few fine dirt scratches	Normal	Fine lines	Normal	Light scratches	Fine scratches	0.1294	No engine repairs were required during the test.
4J2695	CCL-O-147	43.9	4.6	Normal (0.001)	Very light dirt scratches	Normal	Fine lines	Normal	Scratches (copper embedment - copper show on 1)	Scratches (copper showing on 2)	0.1249	Crankshaft broke at 11,480 miles and was replaced along with a new No. 5 main bearing.
4J4623	CCL-O-145	47.5	0.8	Normal (0.008)	Few dust scratches	Normal	Fine scratches	Normal	Light scratches	Few fine scratches	0.0839	No engine repairs were required during the test.
5E5775	CCL-O-146	43.5	3.8	Scuffing (0-90%) (0.008)	Scored (Two severe - two good)	Normal	Scuffing	Some scuffing	25-75% copper surface showing	Copper showing	1.6918	(1) Pan was removed & bearings partially checked at 5,030 miles - all checked as serviceable. (2) The No. 5 rod bearing failed at 7,286 miles and scored the crankshaft. New bearings (rod and main) and a new crankshaft were installed. (3) Rear head (complete with valves & springs) replaced at 8,149 miles. (4) New No. 6 liner and new No. 5 & No. 6 pistons installed at 13,935 miles. (5) Engine consuming antifreeze - crack in No. 6 bore at 14,073 miles. Test was terminated.
5E5774	CCL-O-147	38.9	4.3	Some scuffing (0.002)	Light scratching (one scuffed)	Normal	Scuffing	Normal	Scratches	Fine scratches (copper)	0.4776	(1) The water air manifold cracked - hydraulically locked the engine - was replaced at 748 miles. Fresh oil was added. (2) New heads (including valves, etc.) had to be installed at 10,068 miles. (3) Bearings inspected at 14,025 miles & judged reasonably serviceable.
5E5776	CCL-O-145	42.3	3.2	Normal (0.003)	Good	Normal	Fine lines	Normal	Fine scratching	Fine scratching	0.1733	Rear head (with valves & springs) replaced at 7,432 miles.

*Used high ISD index gasoline.
† Average ring end gap increase, inches.

TABLE 3. OIL SYSTEM IDENTIFICATION AND SAMPLING FREQUENCY

Oil Samples Analyzed at U.S. Army Fuels and Lubricants Research Laboratory

Oil System Sampled*	Sampling Frequency, Miles										
	50	2,000	4,000	6,000	8,000	10,000	12,000	14,000	16,000	18,000	20,000
Engine	X	X	X	X	X	X	X	X	X	X	X
Transmission	X		X		X		X		X		X
Transfer Case†	X		X		X		X		X		X
Rear Axle†	X		X		X		X		X		X

*Oil gallery sampled through permanently installed petcock. Other systems were sampled with a 35-ml syringe (disposable).
†Except M151A1 vehicles.

TABLE 4. FUEL SPECIFICATIONS

I. Gasoline

Property	Spec. Limit		Date Analyzed			
			23 Aug. 1967		20 Feb. 1968	
	Min	Max	Clean	Dirty	Clean	Dirty
Distillation, °F						
10 Percent Evaporated	140	158	140	142		
50 Percent Evaporated	194	239	200	206		
90 Percent Evaporated	275	356	310	322		
Residue, Percent		2	1.0	1.0		
RVP		8	7.1	7.6		
Res. Octane No.	91		96.4	96.8		
Motor Octane No.	83		86.5	87.6		
Gum, mg/100 ml		4	0.8	1.5	1.3*	16.9
ISD, mg/100 ml			0.0	5.8	0.5	9.5
Sulfur		0.25	0.016	0.016		
Corrosion		1	1A	1A		
TEL, ml/gal		3	2.9	2.9		
Oxid. Stab., min	480		1000+	1000+		
Gravity, °API			63.9	63.4		
Color			Red	Red		

*Washed.

II. CITE Fuel

Property	MIL-F-45121B Specifications		Batch 19 708 Tank	Batch 20 708 Tank
	Min	Max		
Gravity, °API			49.2	48.5
Distillation, °F				
Initial	130	160	134	138
10 Percent	200	260	204	205
50 Percent	300	375	342	372
90 Percent	450	500	454	460
End Point		575	484	490
Residue, Percent		2	1	1
Loss, Percent		2	1	1
RVP	1	3	2.8	2.7
Total Sulfur, Percent Weight	0.25	0.4	0.27	0.27

TABLE 4. FUEL SPECIFICATIONS (Cont'd)

Copper Strip Corrosion at 212°F		1	1A	1
Olefin Content, Percent Vol	2.0	5.0	1.7	2.9
Aromatic Content, Vol Percent (D1319)	15.0	25.0	17.6	16.4
Gum Ext. Steam Evap., mg/100 ml		7.0	0.4	1.2
Potential Gum, mg/100 ml		14.0	2.2	4.2
Freezing Point, °F		−67	−73	−72
Kinematic Viscosity				
CS at 100°F	0.9		0.95	1.02
CS at −30°F		16.5	3.5	4.1
Cetane No.	35	40	37.5	37.0
Additives, lb/1000 bbl				
(1) Oxidation inhibitor	5	9	8	8
(2) Metal Deactivator	1	2	2	2
Smoke Point	17		20	19
Thermal Stability				
Change in Press. in 5 hr, in. Hg.		15	0.3	0.1
Preheater/Filter		3	1	1
Deposit 300°F 400°F				
Water Separation Index Mod. WSIM	75		90	100
Mfg Date			3/21/67	8/4/67

III. Caterpillar 1-H Diesel Fuel

Property	Specifications Min.	Specifications Max	Batch 67-8
Gravity, °API	29.7	31.7	31.6
Flash, °F P.M.	Report		206
Pour Point, °F	+10	+20	+15
Cloud Point, °F	Report		+20
Aniline Point, °F	133.2	139.2	135.7
Ramsbottom Carbon, 10 Percent Residuum		0.15	0.07
Kinematic Viscosity at 100°F	3.2	4.0	3.3
Distillation, °F			
IBP	Report		423
10 Percent	468	498	476
50 Percent	515	545	523
90 Percent	600	630	604
E.P.	650	690	677
Total Sulfur, wt Percent (Natural Sulfur)	0.37	0.43	0.38
Cetane No.	40	45	42.9
Water & Sediment		0.05	Nil
Corrosion, Cu Strip, 3 hr 122°F	Pass (1A)		1B
Neut. No.		0.40	–
Cracked Stocks	None		None

TABLE 5. TEST MATERIALS USED IN TRUCKS

Reg. No.	Trailer No.	Engine Oil	Fuel	Gear Oil	Grease	Brake Fluid
1/4-Ton, M151A1 Jeeps						
2J8600	6T9926	CCL-O-145	Dirty	CCL-G-149	400	VV–B-680
2J8645	6T9927	CCL-O-146	Clean	CCL-G-150	233 X 6	VV-B-680
2J8666	6T9930	CCL-O-144	Clean	CCL-G-149	233 X 6	Mil-H-13910
2J8669	6T9929	CCL-O-147	Clean	CCL-G-148	403	Mil-H-13910
2J8693	6T9928	CCL-O-145	Clean	CCL-G-151	234 X 6	Mil-P-46046
3/4-Ton, M37B1						
3B3632	6K8203	CCL-O-146	Clean	CCL-G-148	233 X 6	VV-B-680
3G6207	6K8062	CCL-O-144	Clean	CCL-G-150	234 X 6	VV-B-680
1-1/4-Ton, M715						
3F3072	6K8067	CCL-O-147	Clean	CCL-G-148	403	VV-B-680
3F3078	6K8184	CCL-O-146	Clean	CCL-G-150	400	VV-B-680
3F3175	6K7344	CCL-O-144	Dirty	CCL-G-149	233 X 6	Mil-H-13910
3F3183	6K8166	CCL-O-144	Clean	CCL-G-151	233 X 6	Mil-H-13910
3F3199	6K7871	CCL-O-145	Clean	CCL-G-151	234 X 6	Mil-P-46046
2-1/2-Ton, M35A2						
4J2578	6S1655	CCL-O-146	CITE-R	CCL-G-149	233 X 6	VV-B-680
4J2594	6S1665	CCL-O-147	CITE-R	CCL-G-148	403	VV-B-680
4J2695	6S1648	CCL-O-147	CITE-R	CCL-G-150	233 X 6	Mil-P-46046
4J4609	6S1554	CCL-O-144	CITE-R	CCL-G-150	234 X 6	Mil-P-46046
4J4623	6S1664	CCL-O-145	CITE-R	CCL-G-151	234 X 6	Mil-H-13910
5-Ton, M54A2						
5E5774	7F8155	CCL-O-147	CITE-R	CCK-G-148	403	VV-B-680
5E5775	7F8156	CCL-O-146	CITE-R	CCL-G-149	233 X 6	VV-B-680
5E5776	7F8157	CCL-O-145	CITE-R	CCL-G-150	234 X 6	Mil-P-46046

TABLE 6. DESCRIPTION OF VEHICLES

Vehicle Registration Number	Vehicle Type	Engine Description
2J8600 2J8645 2J8693 2J8666 2J8669	M151A1 (1/4-Ton)	M151 Engine 71 Gross hp at 4000 rpm 128 (lb-ft) Gross Torque at 1800 rpm
3B3632 3G6207	M37B1 (3/4-Ton)	Dodge T245 94 Gross hp at 3400 rpm 188 (lb-ft) Gross Torque at 1200 rpm
3F3183 3F3078 3F3199 3F3072 3F3175	M715 (1-1/4-Ton)	Model 6-230 130 Gross hp at 4000 rpm 198 (lb-ft) Gross Torque at 2000 rpm
4J4609 4J2578 4J2594 4J2695 4J4623	M35A2 (2-1/2-Ton)	LD-465-1 140 Gross hp at 2600 rpm 331 (lb-ft) Gross Torque at 1600 rpm
5E5775 5E5774 5E5776	M54A2 (5-Ton)	LDS-465-1A 210 Gross hp at 2800 rpm 450 (lb-ft) Gross Torque at 2000 rpm

A

TABLE 7. SUMMARY OF ENGINE C

Engine No.	Oil No.	Vehicle	Fuel	Pistons	Bearings	Liners–Combustion Chamber (Head)	Valve–V
2J-8600	CCL-O-145	1/4T	Dirty	5-Dirtiest, sluggish rings w/o deposits	(All Good) 1-Generally O.K.	1-Generally O.K,. high test deposits	5-Heavy valve t
2J-8645	CCL-O-146	1/4T	Clean	2-Next to cleanest, rings free	1-Generally O.K.	3-Generally O.K.	1-Generally O.K
2J-8666	CCL-O-144	1/4T	Clean	1-Cleanest of group, sluggish rings w/o deposit	1-Generally O.K.	5-Light scuff liners–heavy head deposits	1-Generally O.K
2J-8669	CCL-O-147	1/4T	Clean	4-Next to dirtiest of group, sluggish rings w/o deposit	1-Generally O.K.	3-Generally O.K.	2-Light wear on
2J-8693	CCL-O-145	1/4T	Clean	2-Next to cleanest, rings sluggish w/o deposit	1-Generally O.K.	1-Light scratching–high test deposits	3-Intake tulip d heavier
3B-3632	CCL-O-146	3/4T	Clean	1-Cleanest, sluggish rings w/o deposits	(All Poor) 1-Mains overlay worn off, embedded dirt; rods 3 eroded or corroded, 2-Wiping, 1 wiped	1-Deposits light, some liner scratching	3-Heaviest valve
3G-6207	CCL-O-144	3/4T	Clean	2-Dirtiest of two, sluggish ring w/o deposit	1-Generally O.K. at finish, all bearings replaced at 17,000 miles, 1 wiped, all corroded at that time	2-Heaviest deposits, some scuffing #1 liner	1-Generally O.
3F-3072	CCL-O-147	1-1/4T	Clean	5-Dirtiest of 1-1/4T, rings sluggish w/o deposits	(All Relatively Good) 2-Generally O.K.	2-Bores normal, cleaner than average	3-Valve tulip d heavier than
3F-3078	CCL-O-146	1-1/4T	Clean	1-Cleanest of 5 engines, rings sluggish w/o deposits	2-Generally O.K.	4-Head deposits heavier than most	2-Slight heavier deposits
3F-3175	CCL-O-144	1-1/4T	Dirty	4-One of dirtiest, sluggish rings w/o deposits	1-Best condition of group	5-Bores light scratch, heaviest deposits	5-Heavy valve
3F-3183	CCL-O-144	1-1/4T	Clean	3-One of cleanest, cold stuck rings some deposits	2-Generally O.K.	3-Bores scratch, heavier than most	3-Intake valve than normal
3F-3199	CCL-O-145	1-1/4T	Clean	2-One of cleanest, all rings free	3-Overlay flaking, some on 2 rod bearings	1-Cleanest of 5 engines	3-Intake valve than normal
4J-2578	CCL-O-146	2-1/2T	CITE-R & Diesel	1-Cleanest of group, all rings free	(All Mediocre) 3-Mains medium scratching or gouging	3-Bores fine scratch, head deposits medium	2-#2 exhaust
4J-2594	CCL-O-147	2-1/2T	CITE-R & Diesel	4-Dirtiest of group	1-Relatively good	4-#4 bore heavy gouging, head deposits heaviest	1-Generally O.
4J-2695	CCL-O-147	2-1/2T	CITE-R & Diesel	4-Dirtiest of group #4 rings sluggish w/o deposits	5-Mains badly scratched, dirt embedded mains and rods	1-Bores scratched, head deposits lightest	2-3 Cam follo light wear
4J-4609	CCL-O-144	2-1/2T	CITE-R & Diesel	2-Cleaner of group, #4 ring sluggish w/o deposit	3-Mains well scratched	4-1/8 in. Scuff band #3, one of heaviest on deposits	1-Light wear stems
4J-4623	CCL-O-145	2-1/2T	CITE-R & Diesel	2-Cleaner of group, 1 ring sluggish w/o deposit	2-Relatively good	2-Average deposits	3-Exhaust val
5E-5774	CCL-O-147	5T	CITE-R & Diesel	2-Groove carbon filling may influence scuffing; dirtiest, MAN cup and crown severe erosion; deposits extremely heavy, #6 skirt scuff from skirt carbon, no coke in annulus	(All Poor) 2-Extremely heavy dirt embedded, overlay worn off–#4 worst, rods better than mains	3-#3 light scuff–#4, 5, 6 heavy scuff, head deposits heaviest	5-Valve face & lifter bodies
5E-5776	CCL-O-146	5T	CITE-R & Diesel	3-Groove carbon filling may influence scuffing, #1 & 3 piston skirt scuff #1 piston #2 & 3 land scuffed w/coke in annulus at this location	3-Worst; mains heavy gouging, worn thru overlay; journals ridged, 1 crank & bearing set mediocre during test, wiped 5 rod	2-Bores #5 heavy scuff–#6 scratch, deposits heavy	1-Generally
5E-5776	CCL-O-145	5T	CITE-R & Diesel	1-Deposits heavy, cleanest of 3, no distress	1-Best of groups, 1 main heavy scratch	1-Best no scuffing, front head cracking	3-Intake wear

13

ENGINE OIL PERFORMANCE

Valve–Valve Train	Injection System	Piston Rings	Miscellaneous	Sludge
-Heavy valve tulip deposits	–	3-Generally O.K.	4-Light scuffing rocker shaft; lighter lacquer	5-Generally clean
-Generally O.K.	–	1-Best rings (cleanliness & faces)	1-Very light scuffing on rocker shaft	4-Cleanest of group
-Generally O.K.	–	4-Some light scuff and light scratching	3-Light scuff on rocker shaft, 2 cylinders leaking	2-Generally clean
-Light wear on rocker arm tips	–	5-Light scratching, 10-15% oil ring slot clog, heavy deposits	5-Scuffing on rocker shaft, traces of lacquer, 2 cylinders leaking	1-Light sludge
-Intake tulip deposit generally heavier	–	1-Faces normal & clean	2-Light scuffing on rocker shaft	3-Midrange on sludge
-Heaviest valve tulip deposits	–	1-Generally normal, scratching scuff on #6	1-Generally O.K.	1-Cleanest, some rust in pan
1-Generally O.K.	–	2-Some scuff 2-10% on 2 top rings	1-Generally O.K.	2-Generally low
3-Valve tulip deposits slightly heavier than normal	–	3-Normal w/hard carbon on back	1-Generally O.K.	5-Slight amount of sludge
2-Slight heavier valve tulip deposits	–	2-Normal w/light scratching one of best 1-1/4T	1-Generally O.K.	2-Cleaner of 1-1/4T
5-Heavy valve deposits	–	4-Lacquer and carbon of face and side	1-Generally O.K.	4-Dirtiest of group
3-Intake valve deposits heaver than normal	–	4-Normal w/light scratchi‹ ç	1-Generally O.K.	1-Cleanest of 1-1/4T
3-Intake valve deposits heavier than normal	–	1-Best of group	1-Generally O.K.	3-Midrange of sludge
			1-10% light rust oil cooler, rocker shaft light copper streaking	2-Best of group
2-#2 exhaust tappet trace scuffing	3-Slight deposit, 2150-2260 psi open, 3 nozzles chatter	1-Normal, medium scratch, #1 ring on #6 piston broke in use, scratched	4-General rust oil cooler, push rod & rocker; heavy lacquer & deposit	3-Poorer of group, but clean
1-Generally O.K.	1-All chatter, 2150-2250 psi open, 1 orifice partially plugged	5-Oil, some sludge, top #4 & #6 broke, top #1 & #2 scuff	4-Slight pitting on rocker arm shaft, #8 lacquer deposit	5-Poorest of group, 30% oil suction cover w/permatex
2-3 Cam followers did not light wear	2-1 did not chatter, 2000-2200 psi except #5-1800	4-Faces normal, #6 light scuff #4 & #6 slight discolor	3-50% Rust oil cooler	4-Normal for group
1-Light wear on exhaust valve stems	4-2 Good chatter, 2000-2200 psi, black film on fuel filter	2-Top #3 & #4 broken, second #2 & #3 scuff, #6-10% scuff	2-10% Rust oil cooler, light wear rocker arm tips, push rods #2 lacquer	1-Cleanest of group
3-Exhaust valve stems trace wear	5-#6 1250 psi; #4 1400 psi; no chatter, wide seat; rest 1725-2050 psi	3-Normal w/some scratching	3-5% Rust oil cooler, heavy (#9) varnish push rods, turbo free	3-Heaviest of all engines
5-Valve face & seat heavy wear, lifter bodies heavy lacquer	3-1-1/2 chatter, 1800-2150 psi	3-Cylinder 3, 4, 5, 6, all ring 25-90% scuff, worst cleanliness	1-10% Rust oil cooler, heavy trace lacquer rocker arm, turbo free	1-Heavy sludge
1-Generally less than normal	2-2 Chatter, 1950-2100 psi, 2 split sprays	1-Oil rings 5-90% light scuff, condition less than normal	2-10% Rust oil cooler, push rods #4 lacquer, turbo spotty binding	2-Heavy, intermediate of 3 engines
3-Intake wear, exhaust seat wear	1-2-1/2 Chatter, 2000-2150 psi	2-Light to medium face scuffing		

TABLE 8. TABULATION OF AXLE GEAR TOOTH DISTRESS
IN 1/4-TON, M151 JEEPS AT 20,000 MILES

Vehicle & Lubricant	Distress*	Rear Axle				Front Axle			
		Pinion		Ring		Pinton		Ring	
		Drive	Coast	Drive	Coast	Drive	Coast	Drive	Coast
2J8600 CCL-G-149	Scoring Ridging	Medium		Medium		Light		Light	
2J8645 CCL-G-150	Scoring Ridging		†			Light		Light	
2J8666 CCL-G-149	Scoring Ridging	Trace		Trace		Light, 100%	Light, 50%	Light, 100%	Light, 50%
2J8669 CCL-G-148	Scoring Ridging	Light, 10%		Light, 10%					
2J8693 CCL-G-151	Scoring Ridging	Light, 20%		Light, 20%		Light, 100%		Light, 30%	

*For clarity in this table, where no distress was apparent the tabulation was left blank.
†The rear axle in unit 2J8645 failed at 19335 miles for reasons not believed related to the lubricant.

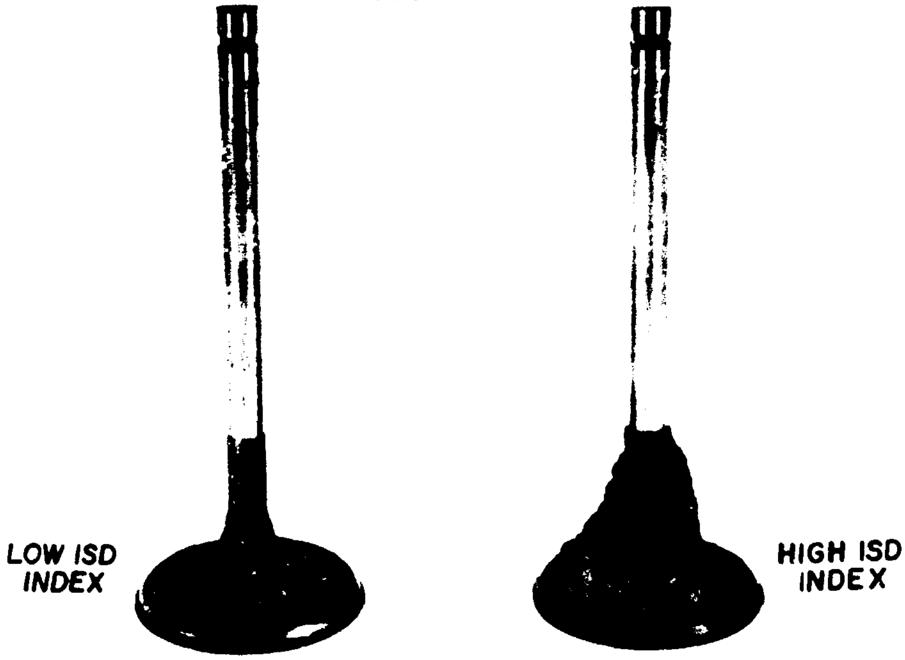
FIGURES

LIST OF FIGURES

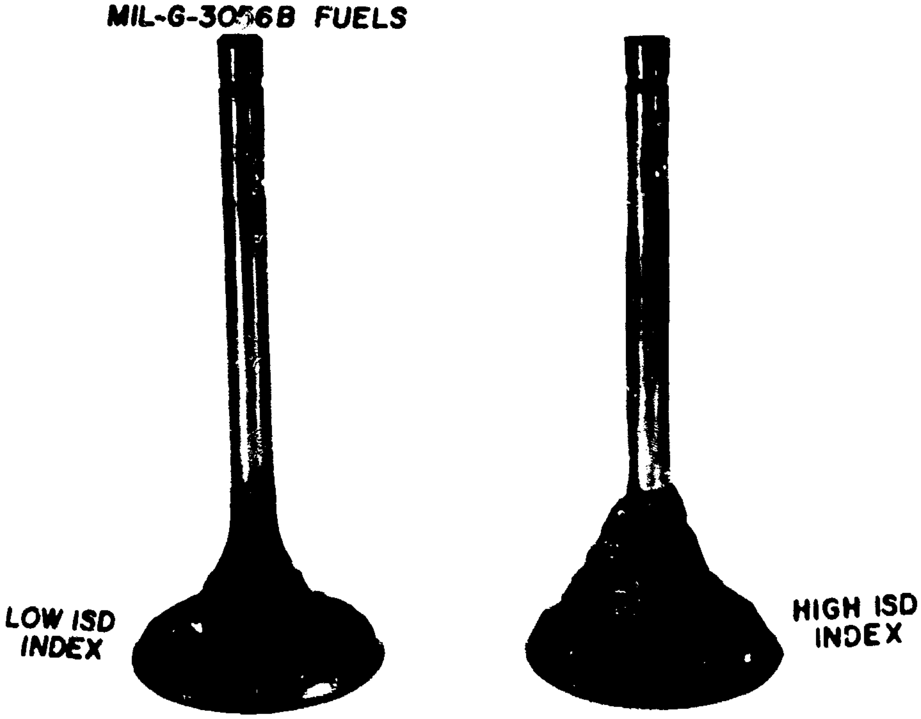
LIST OF FIGURES (Cont'd)

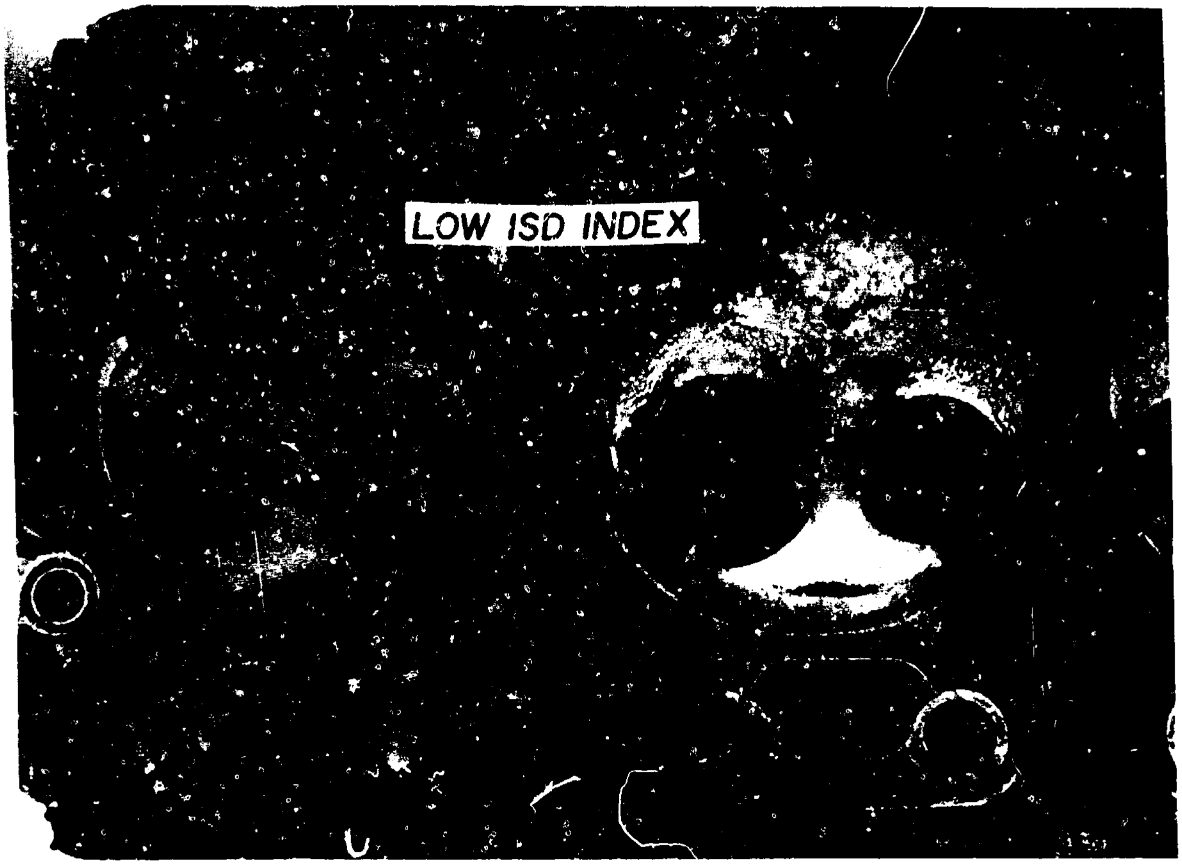

CRANKSHAFT FAILURE IN 2 1/2 TON
TRUCK NO. 4J-2695 AT 11,480 MILES

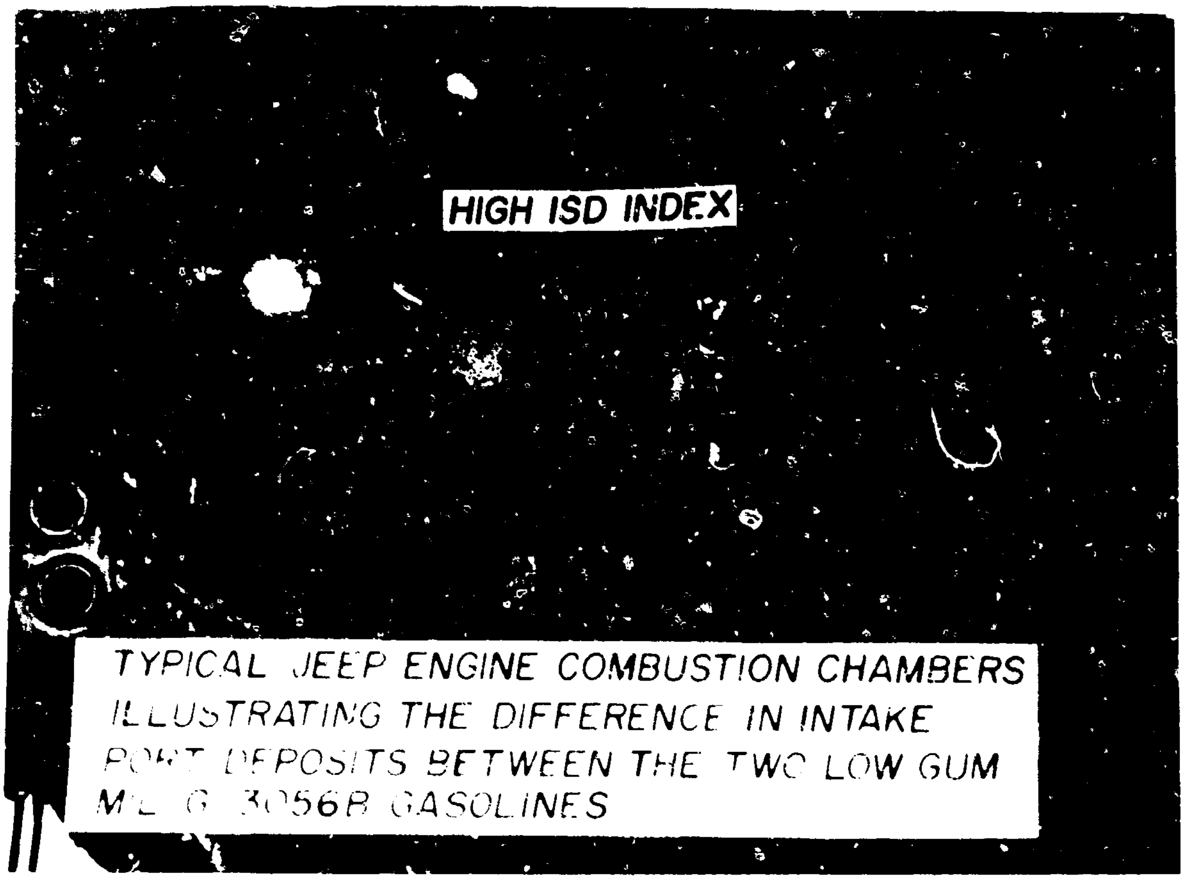
TYPICAL JEEP INTAKE VALVES ILLUSTRATING THE DIFFERENCE IN INTAKE SYSTEM DEPOSITION BETWEEN TWO LOW GUM MIL-G-3056B FUELS



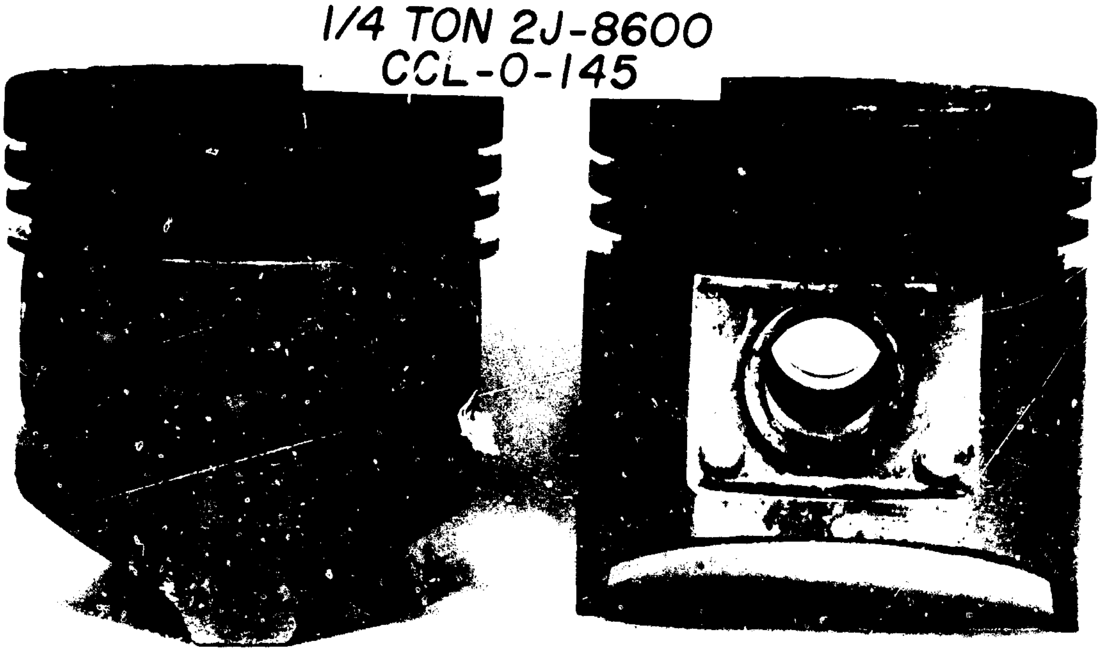
TYPICAL M715 INTAKE VALVES ILLUSTRATING THE DIFFERENCE IN INTAKE SYSTEM DEPOSITION BETWEEN TWO LOW GUM MIL-G-3056B FUELS

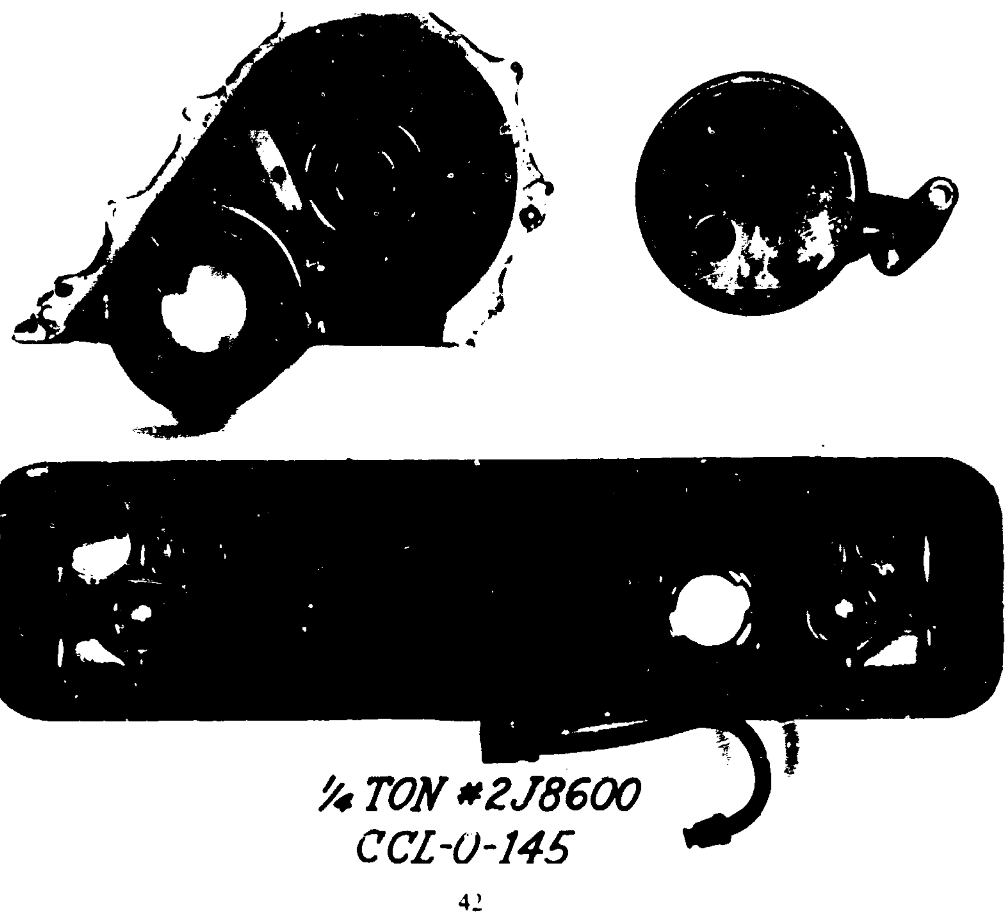




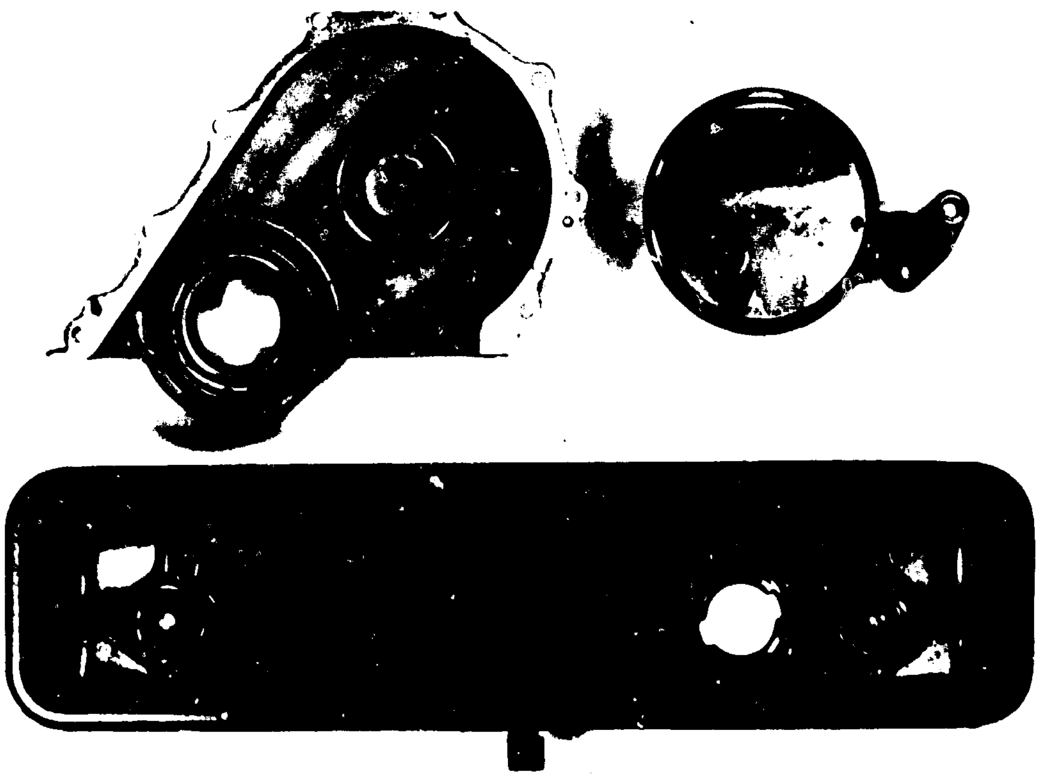


TYPICAL JEEP ENGINE COMBUSTION CHAMBERS ILLUSTRATING THE DIFFERENCE IN INTAKE PORT DEPOSITS BETWEEN THE TWO LOW GUM MIL-G-3056B GASOLINES


1/4 TON 2J-8600
CCL-0-145

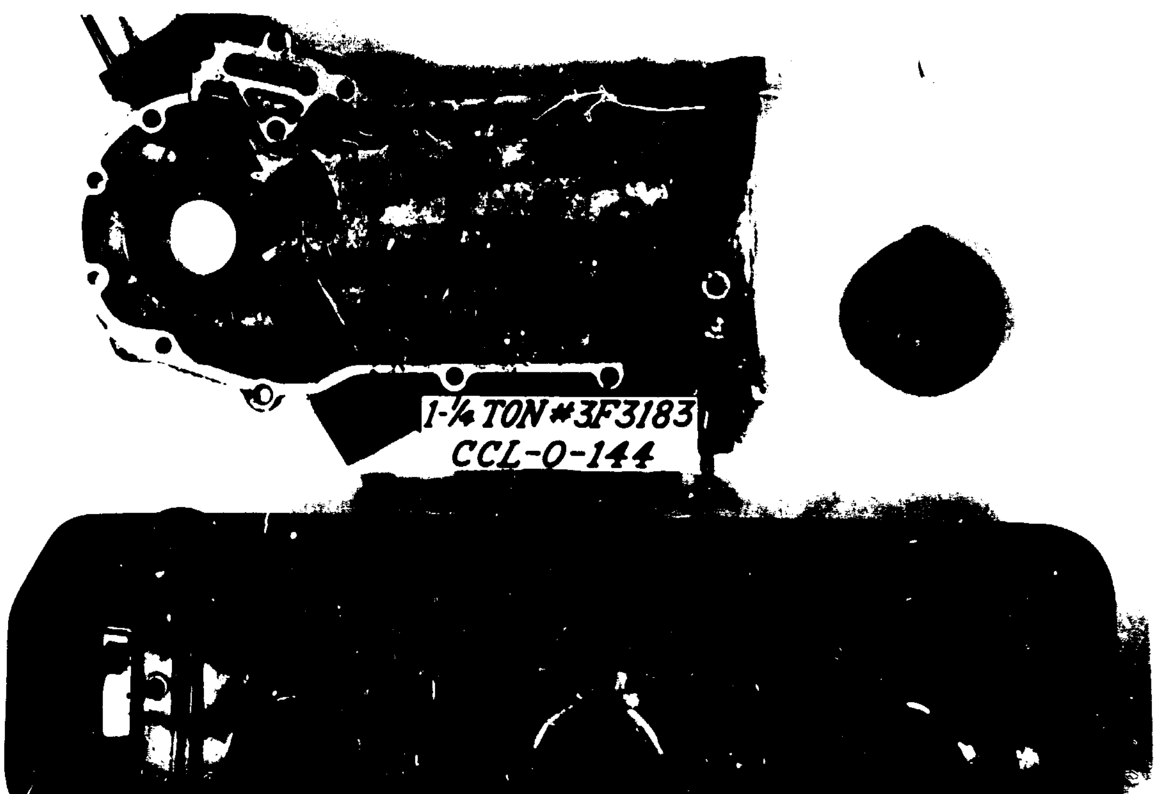

¼ TON #2J8600
CCL-0-145

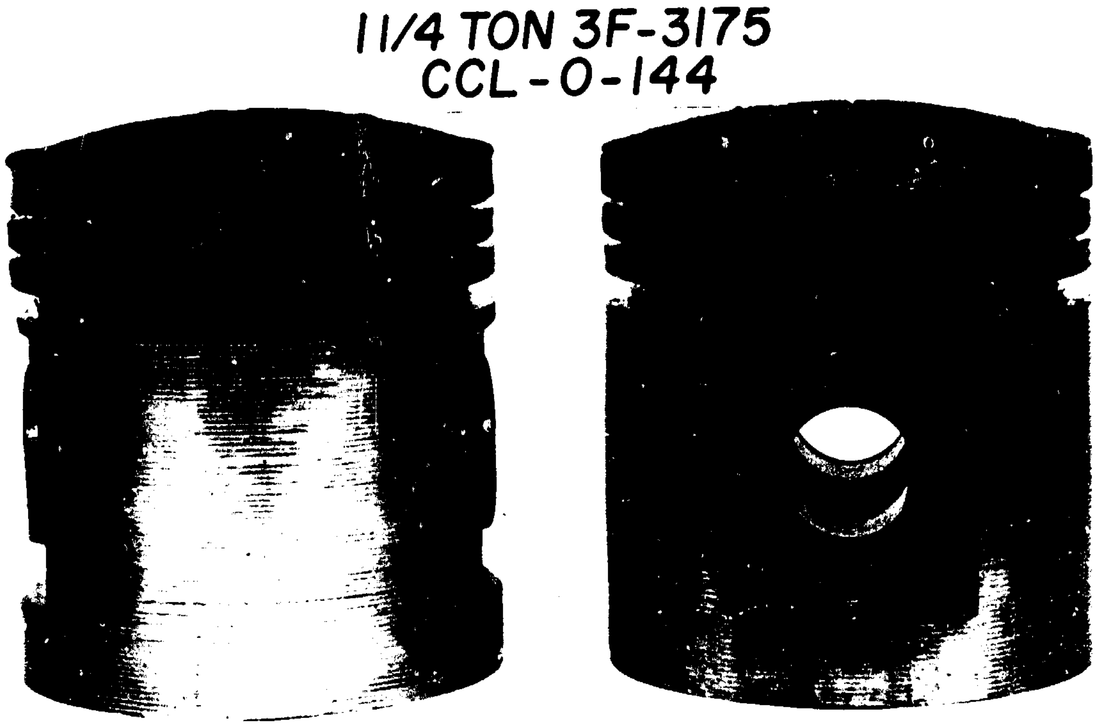
1/4 TON 2J-8666
CCL-0-144



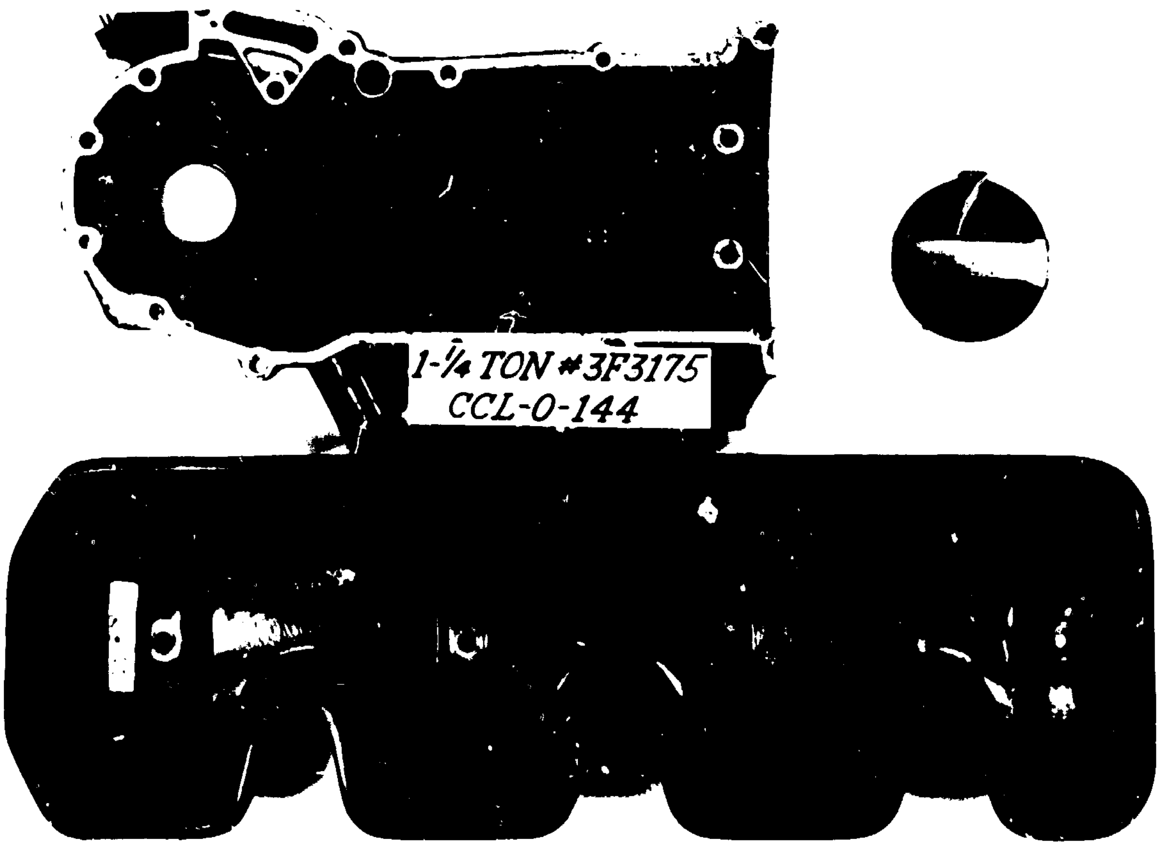
¼ TON #2J8666
CCL-0-144


11/4 TON 3F-3183
CCL-0-144


1-¼ TON #3F3183
CCL-0-144

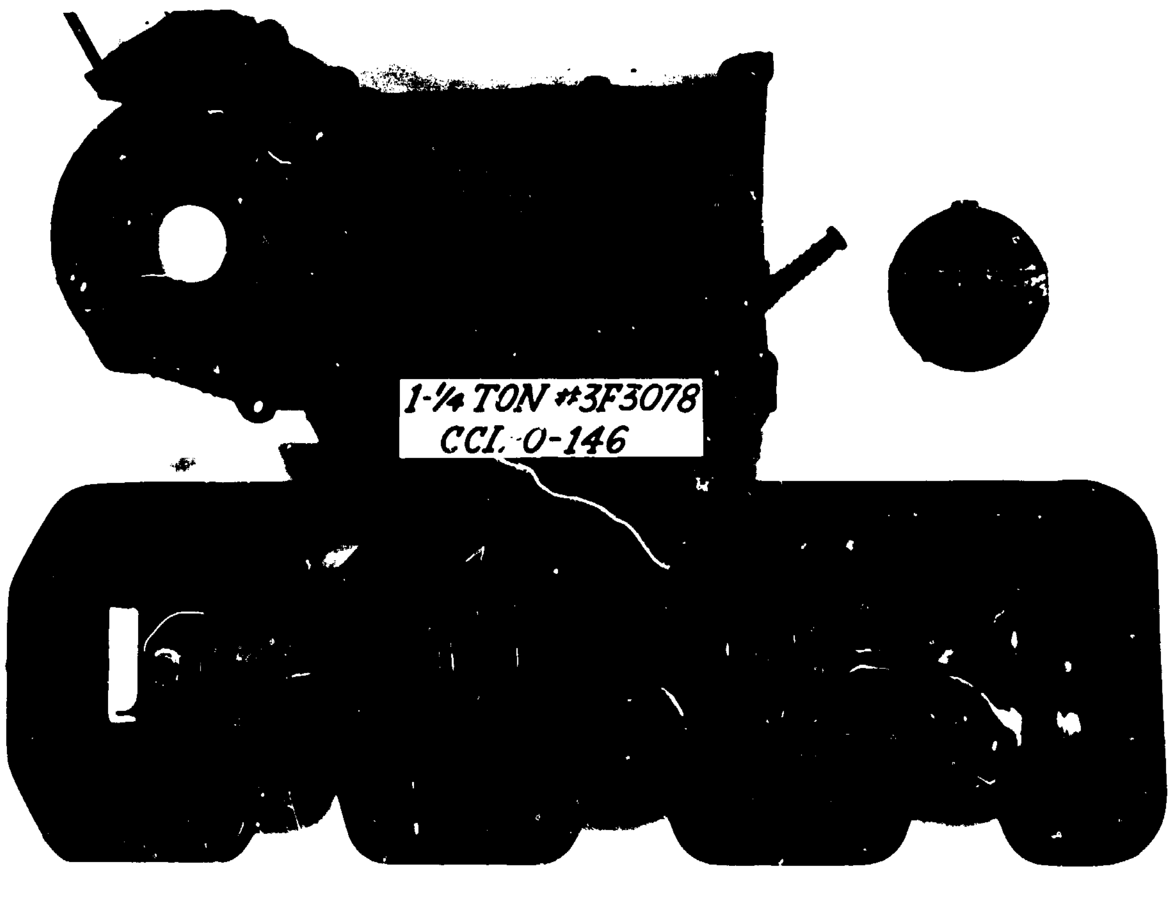


11/4 TON 3F-3175
CCL-0-144



1-1/4 TON #3F3175
CCL-0-144


1 1/4 TON 3F-3078
CCL-0-146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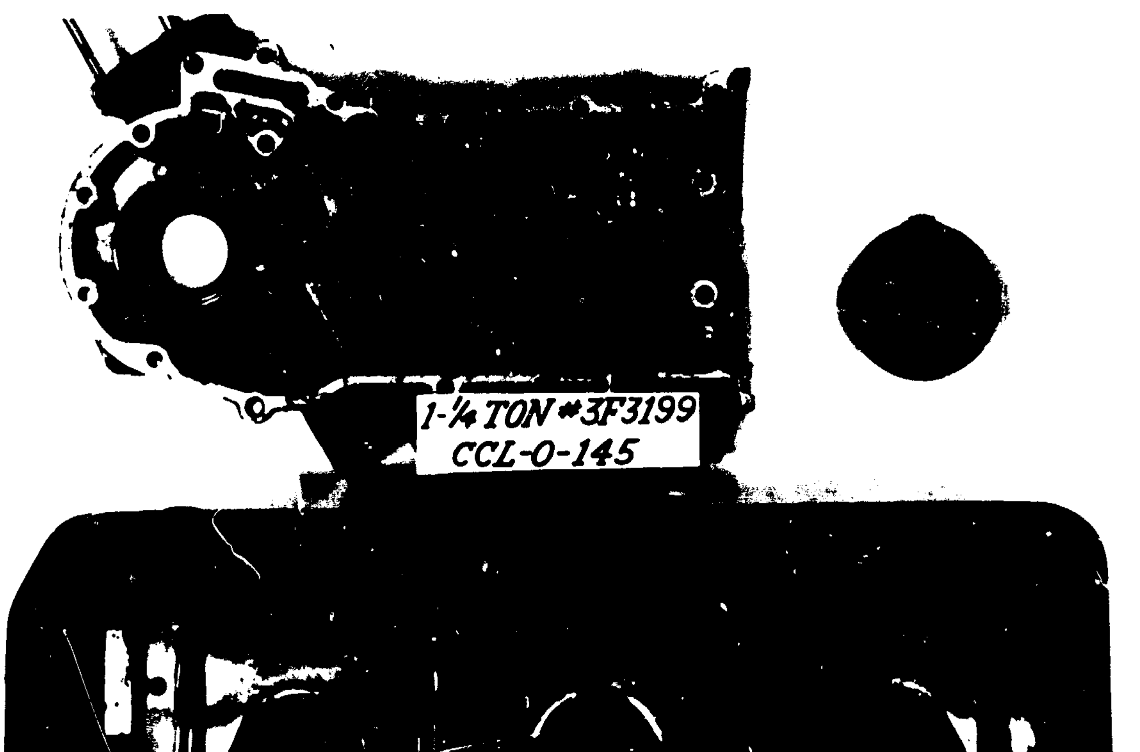
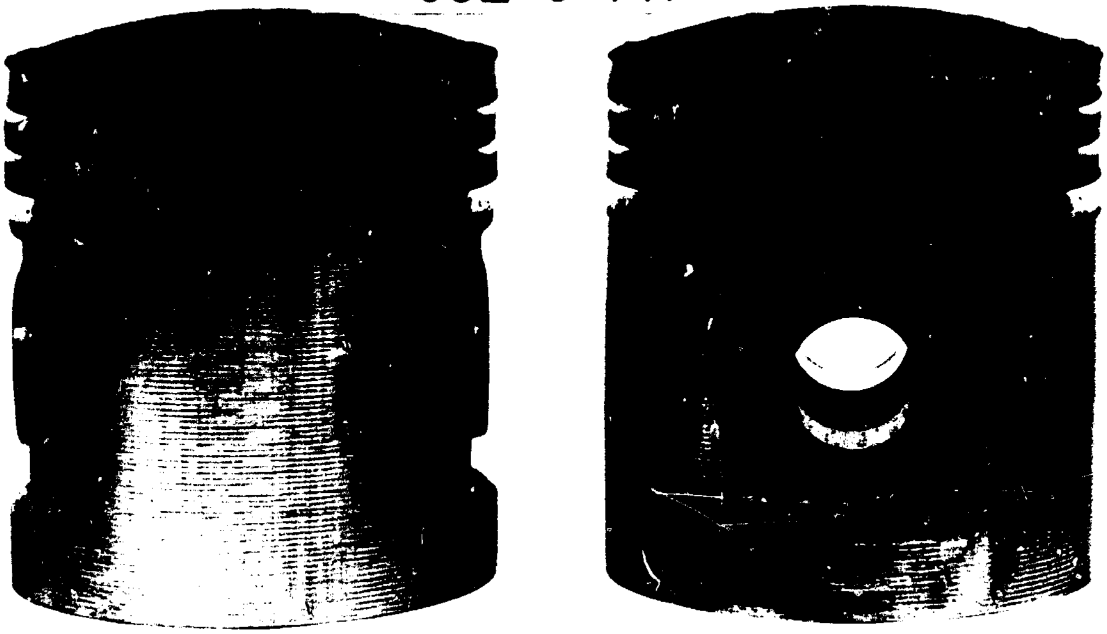
CCL 0-146

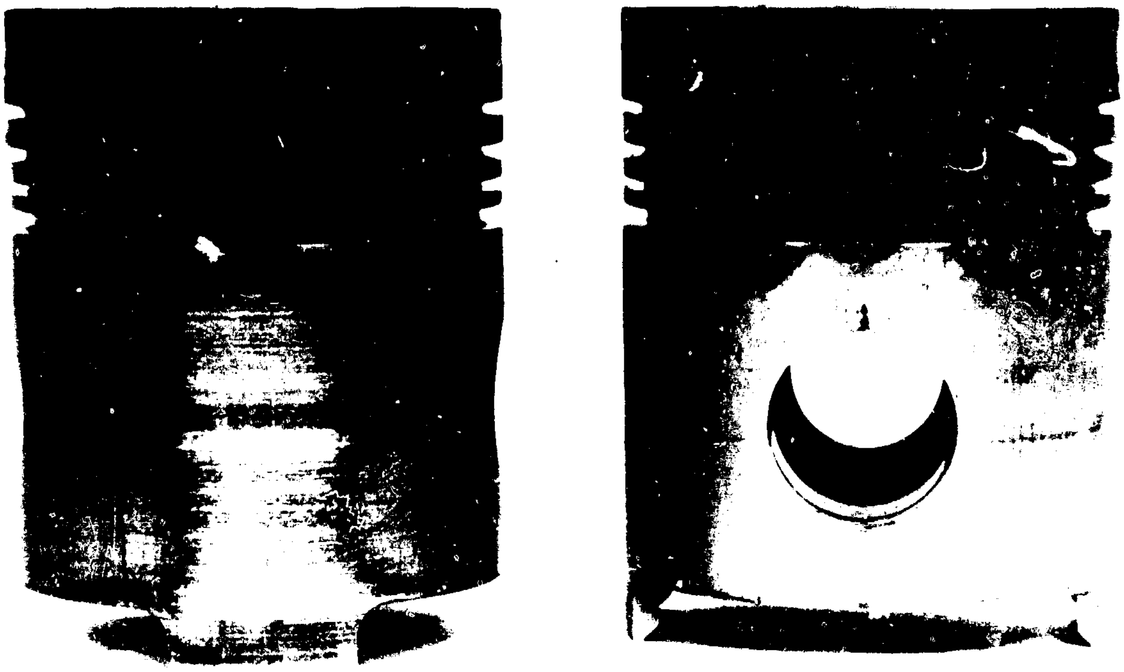
11/4 TON 3F-3199
CCL-0-145



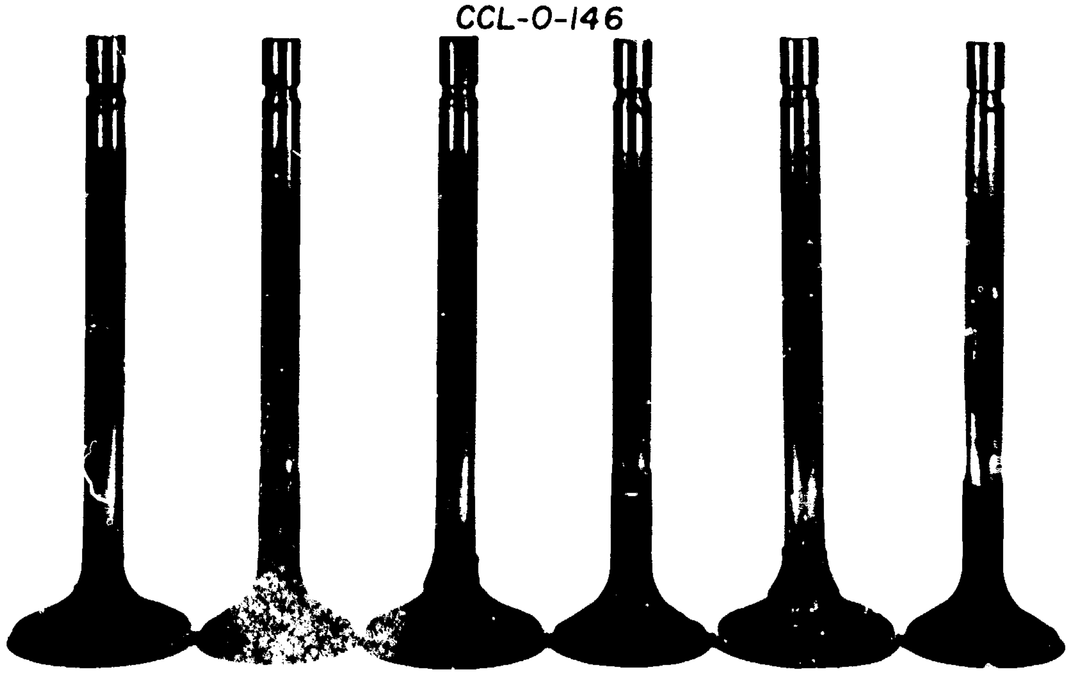
11/4 TON 3F-3072
CCL-0-147



2 1/2 TON 4J-2578
CCL-O-146

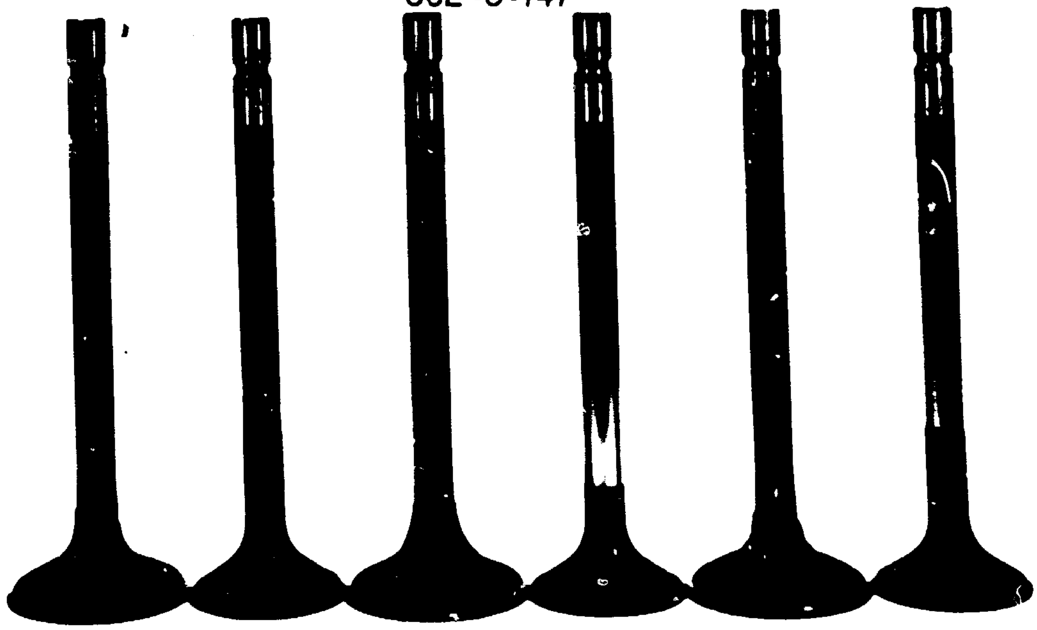


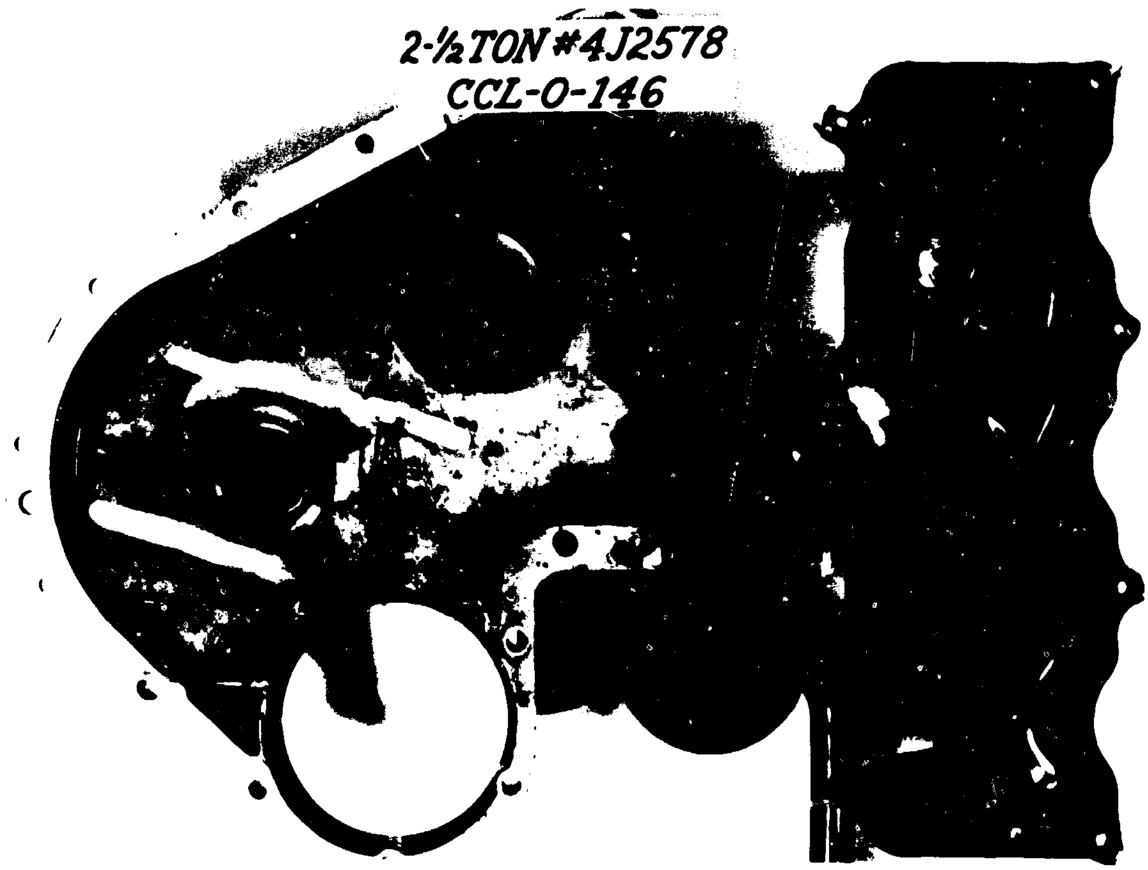
2 1/2 TON 4J-2578
CCL-O-146



2 1/2 TON 4J-2594
CCL-O-147

2 1/2 TON 4J-2594
CCL-O-147

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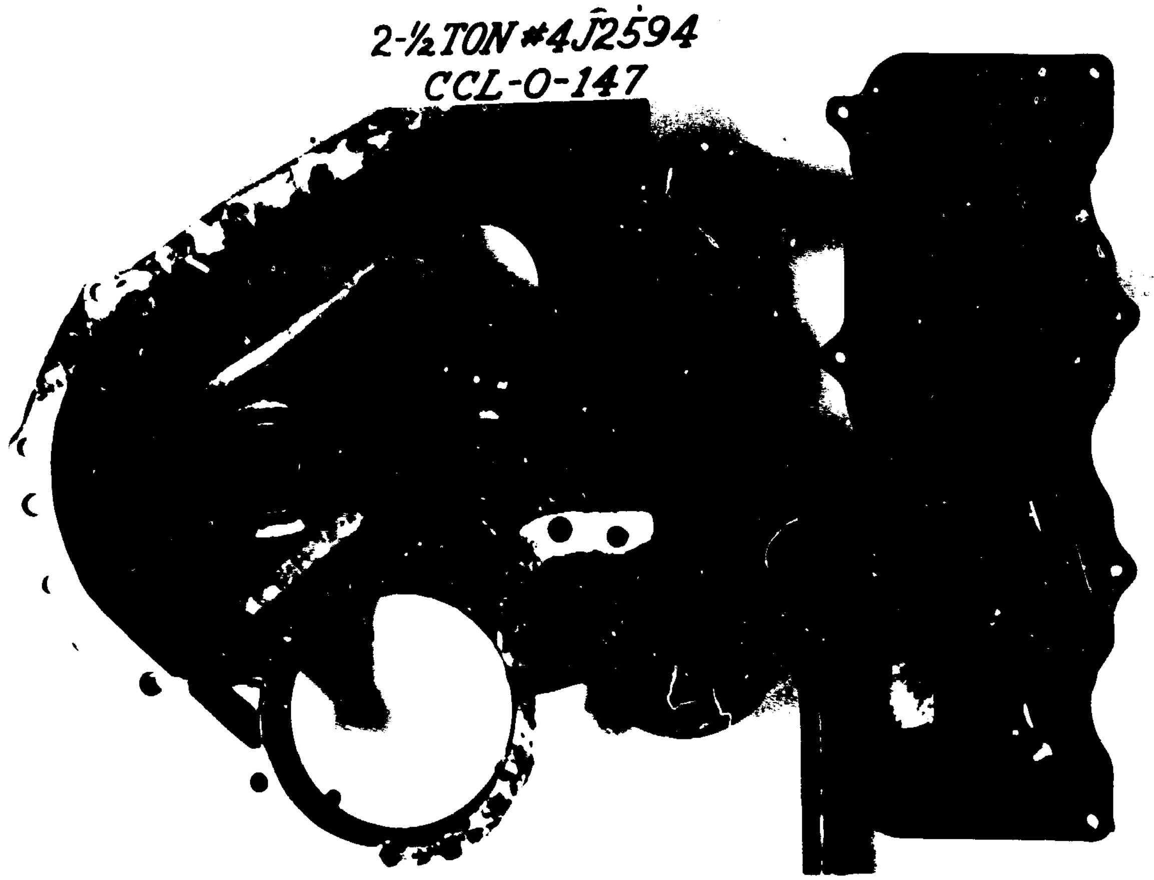
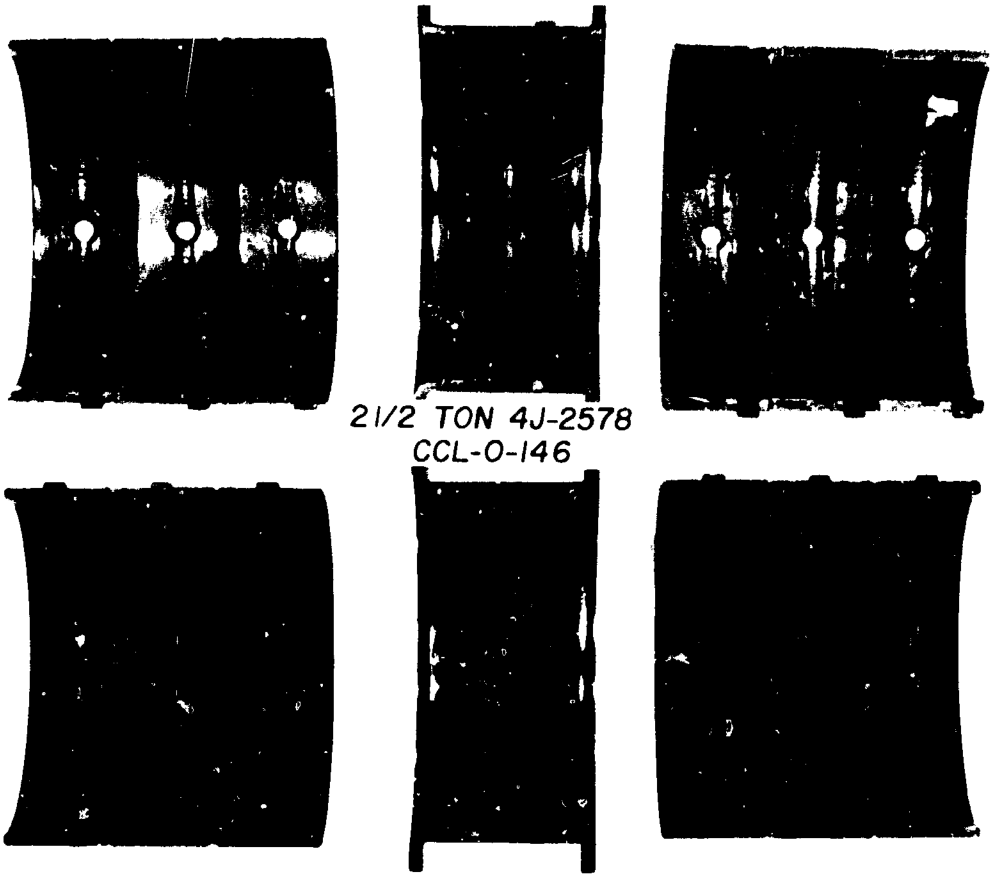
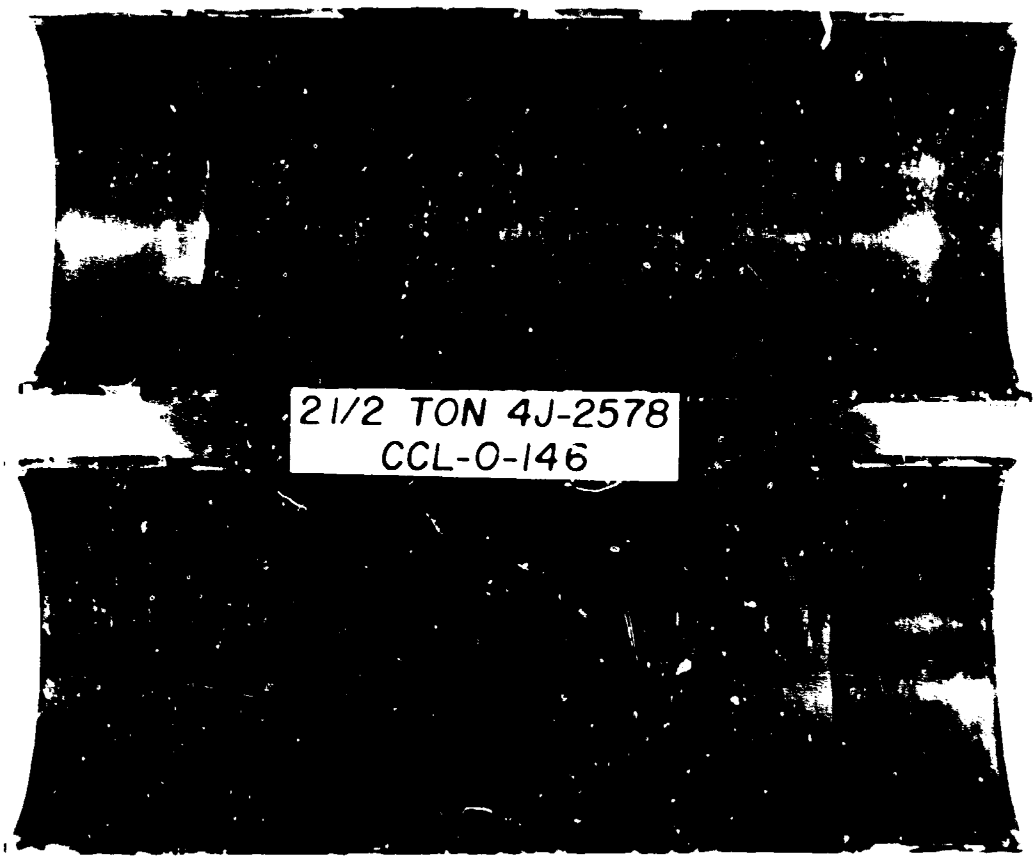
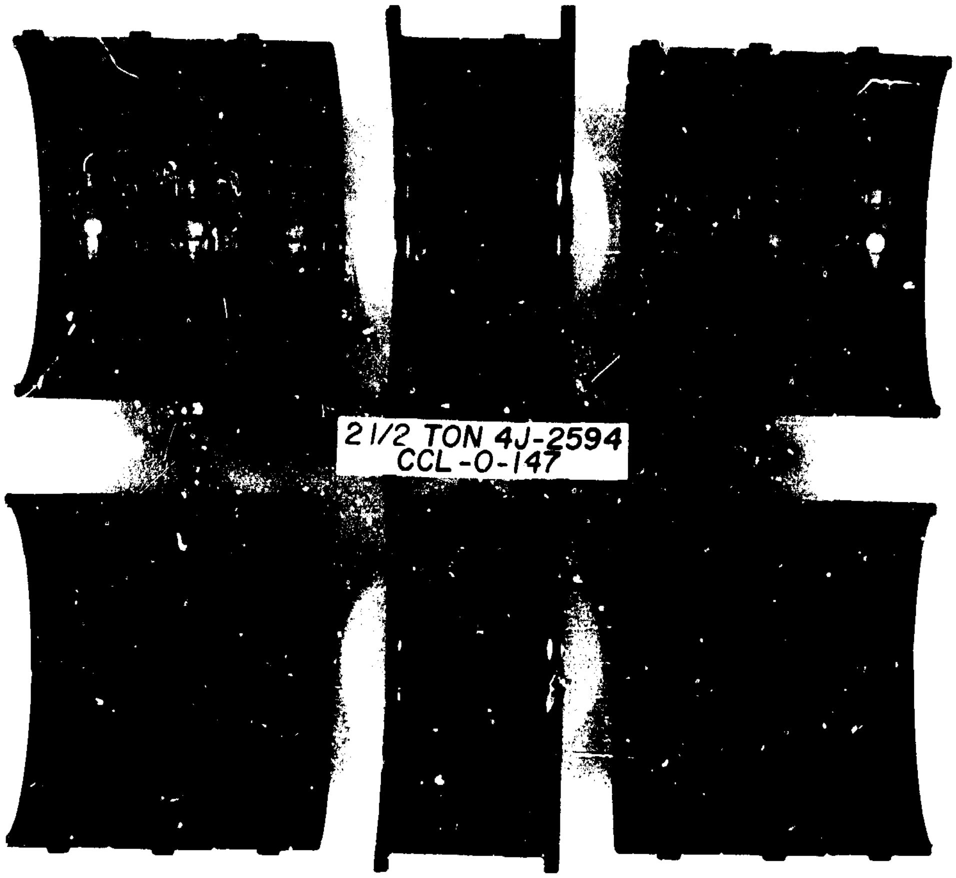
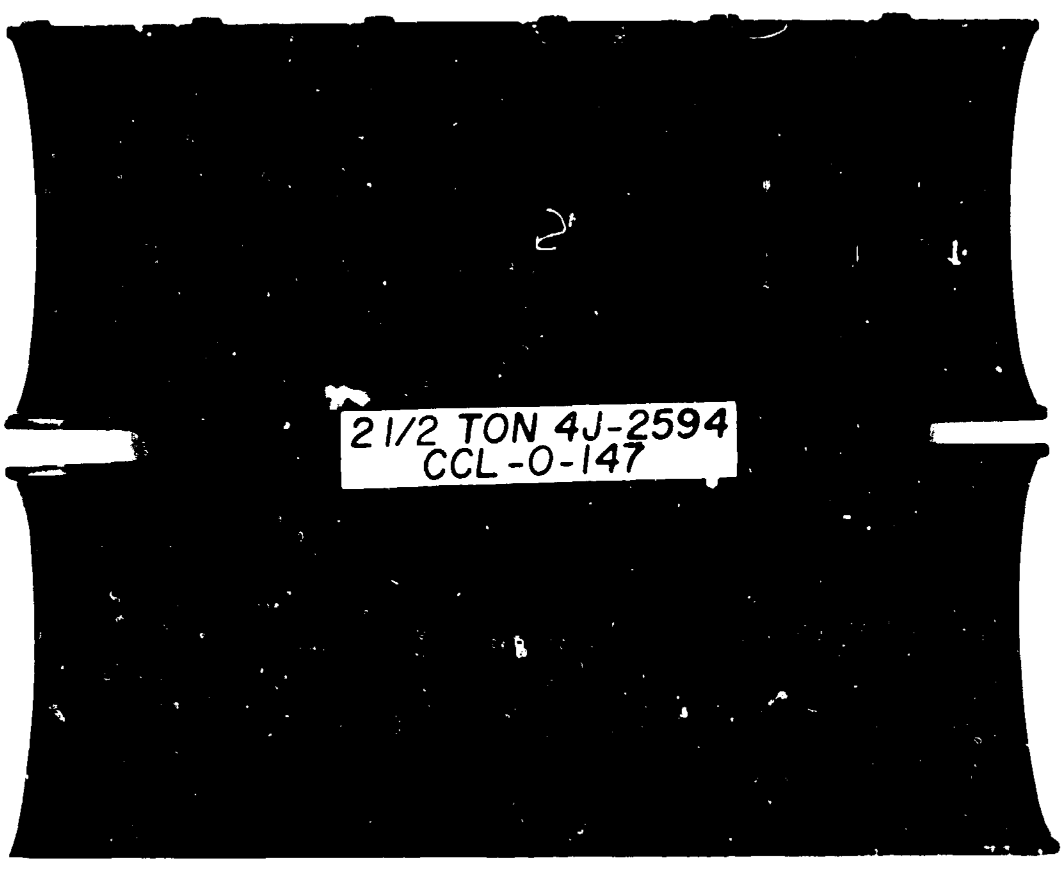
CCL-0-146


2-½TON #4J2594
CCL-0-147


21/2 TON 4J-2578
CCL-O-146


21/2 TON 4J-2578
CCL-O-146


2 1/2 TON 4J-2594
CCL-0-147


2 1/2 TON 4J-2594
CCL-0-147

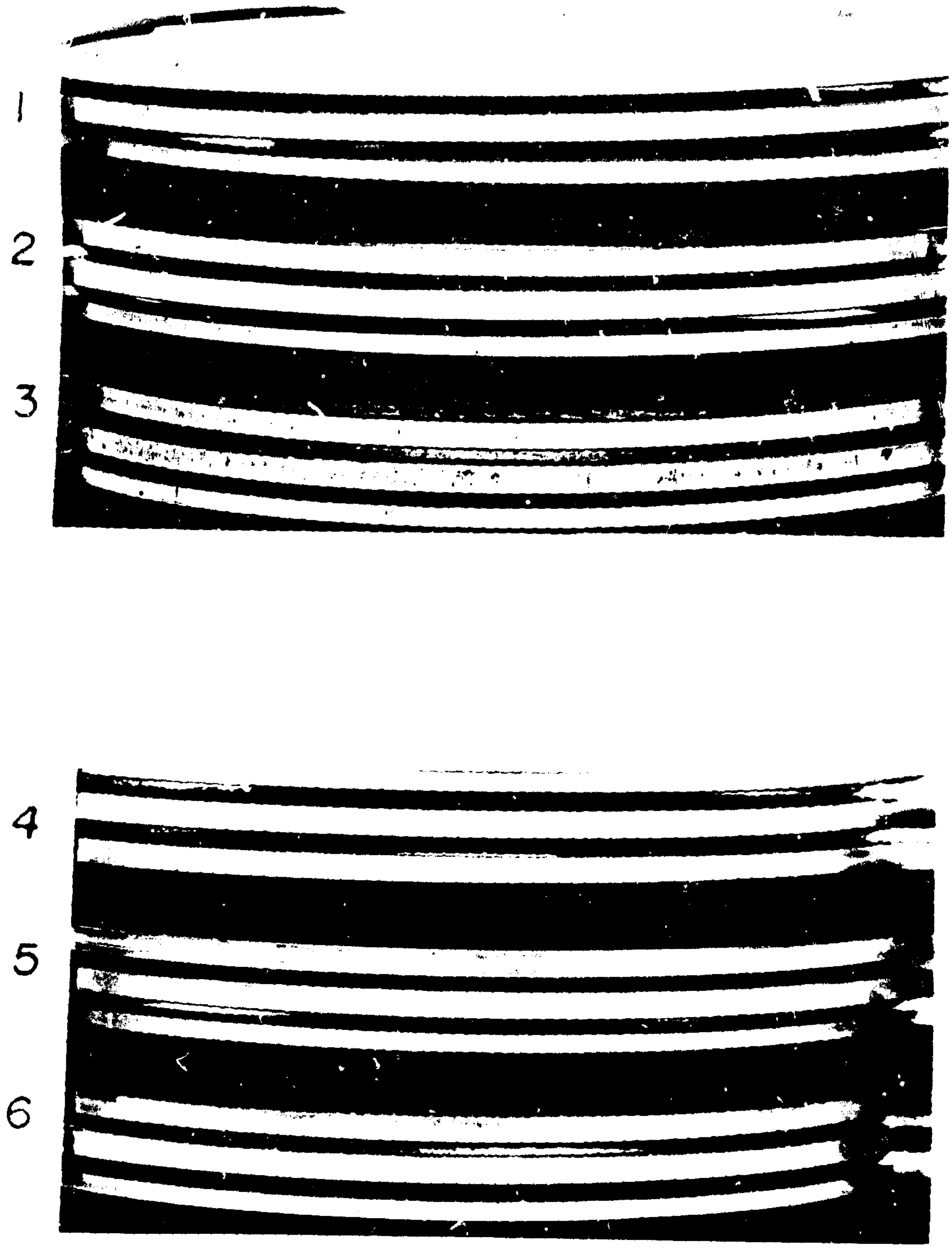


Illustration of the condition of the piston rings in the engine of 5 ton truck #5E5776 after 20,000 miles with CCL-0-145 oil.

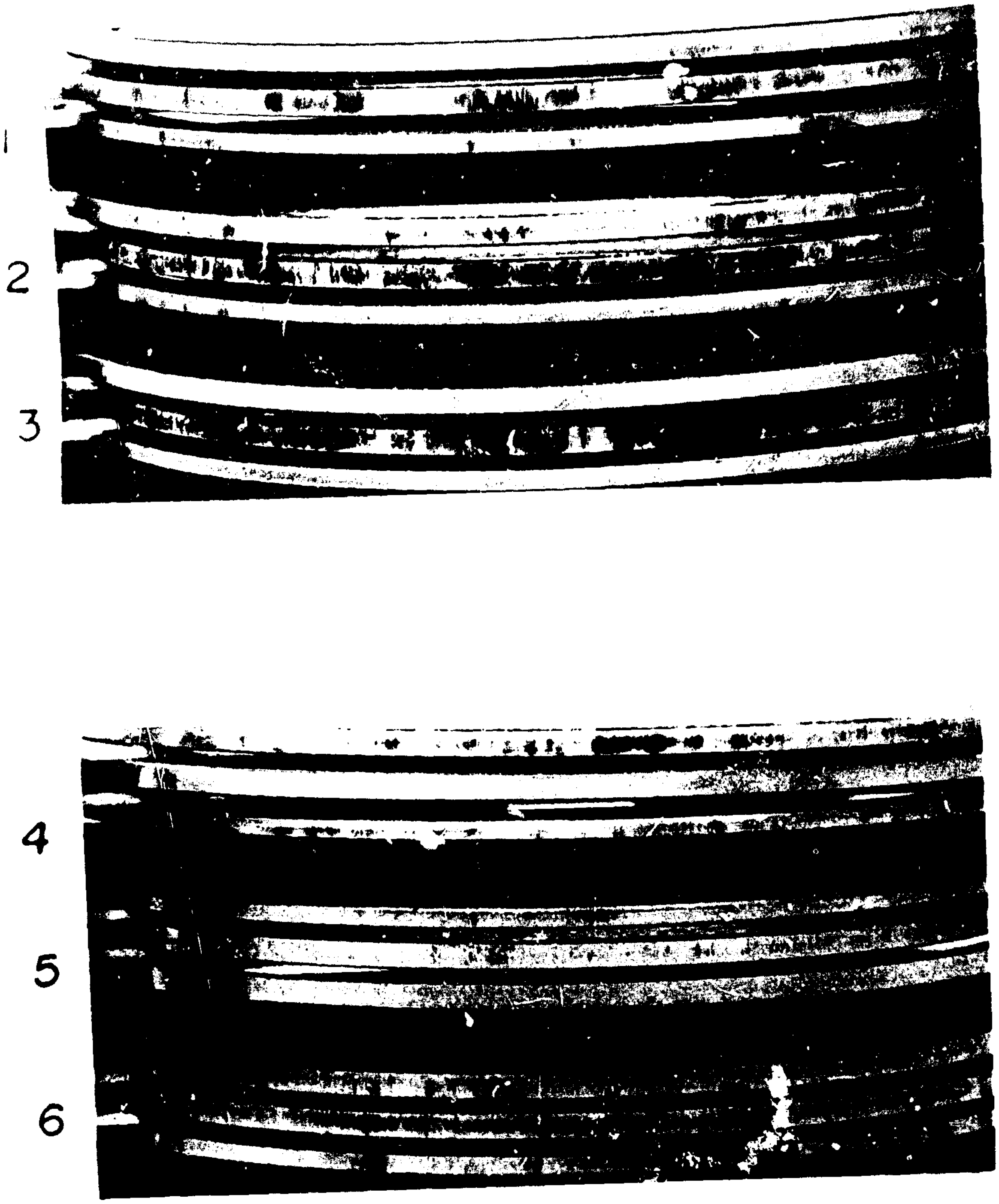
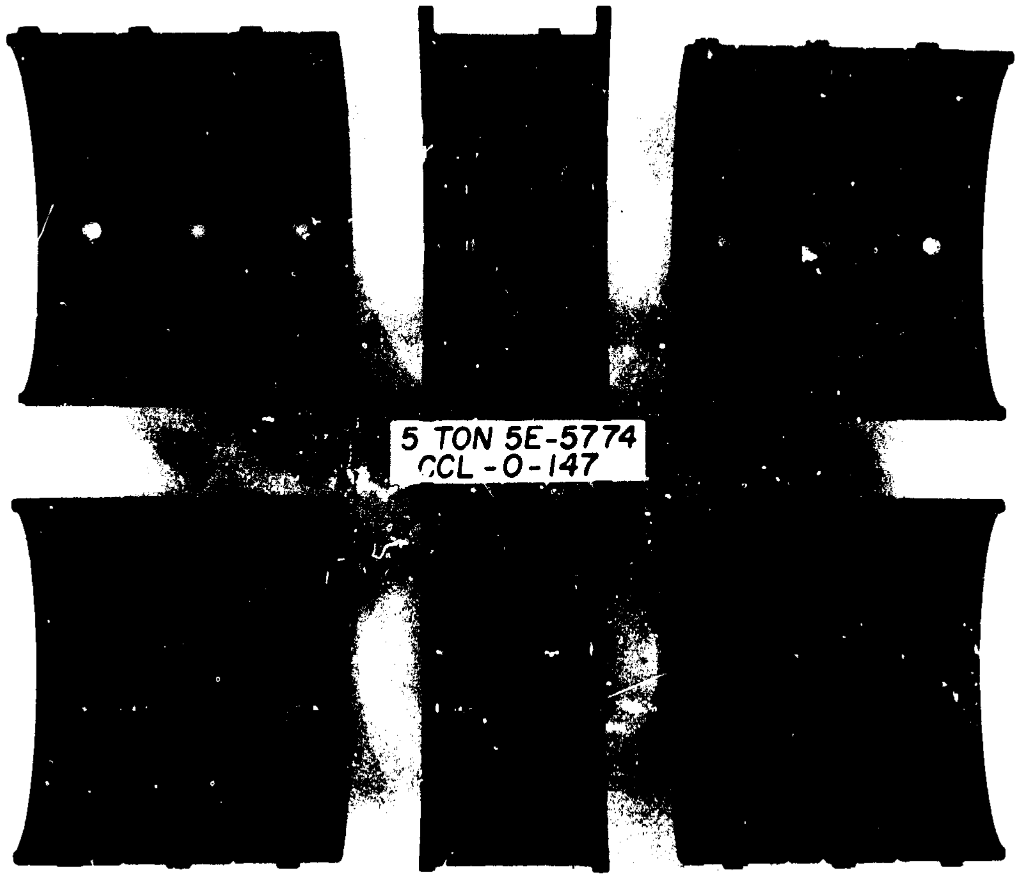
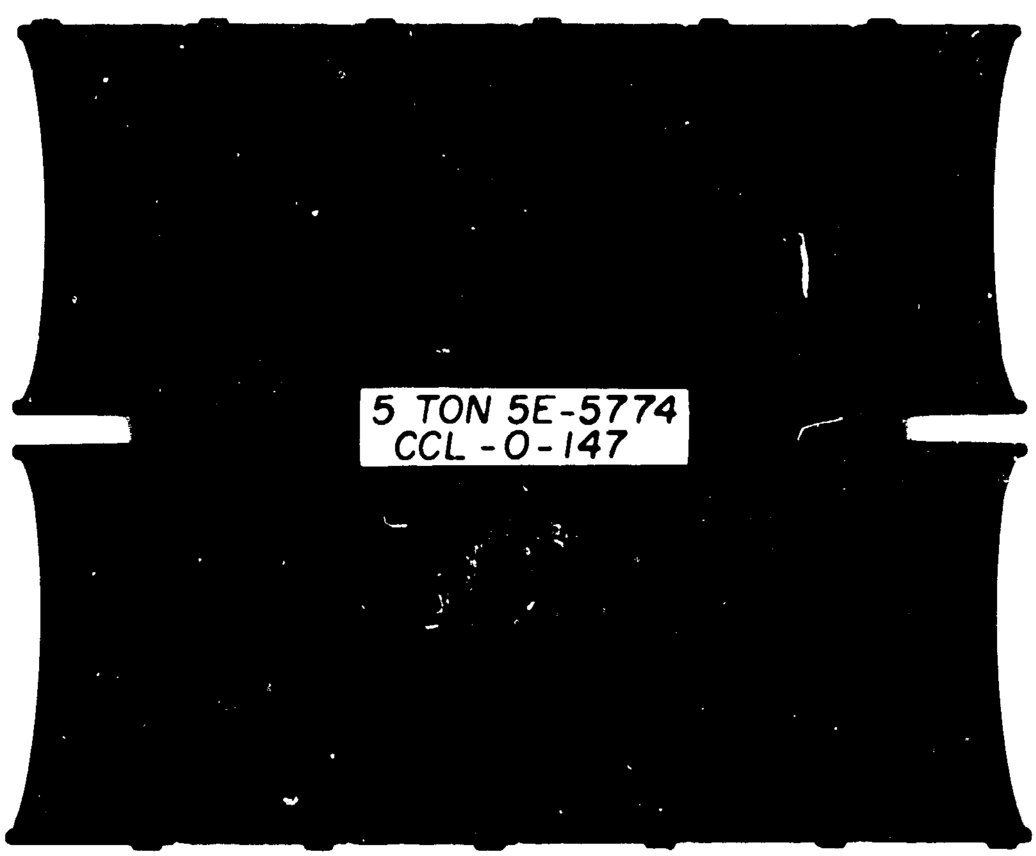
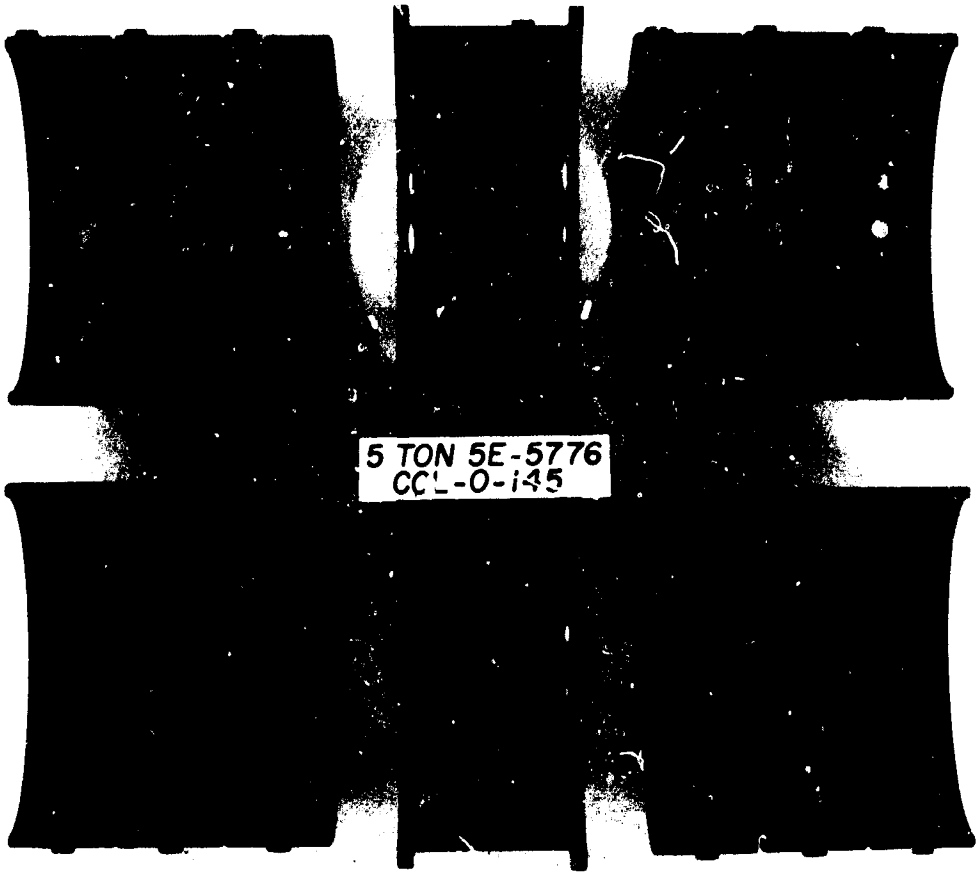


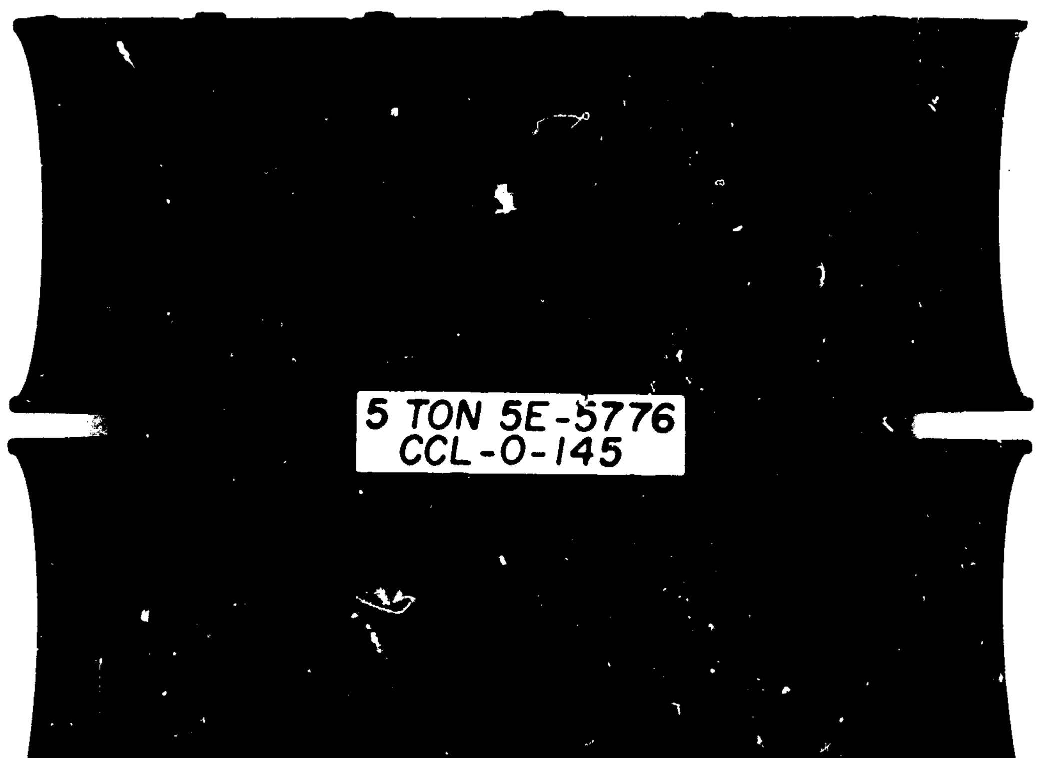
Illustration of the extent of piston ring scoring in the engine of 5 ton truck #5E5775 after 14073 miles with CCL-0-146 oil.

Illustration of the extent of piston ring scoring in the engine of 5 ton truck #5E5774 after 17451 miles with CCL-0-147 oil.

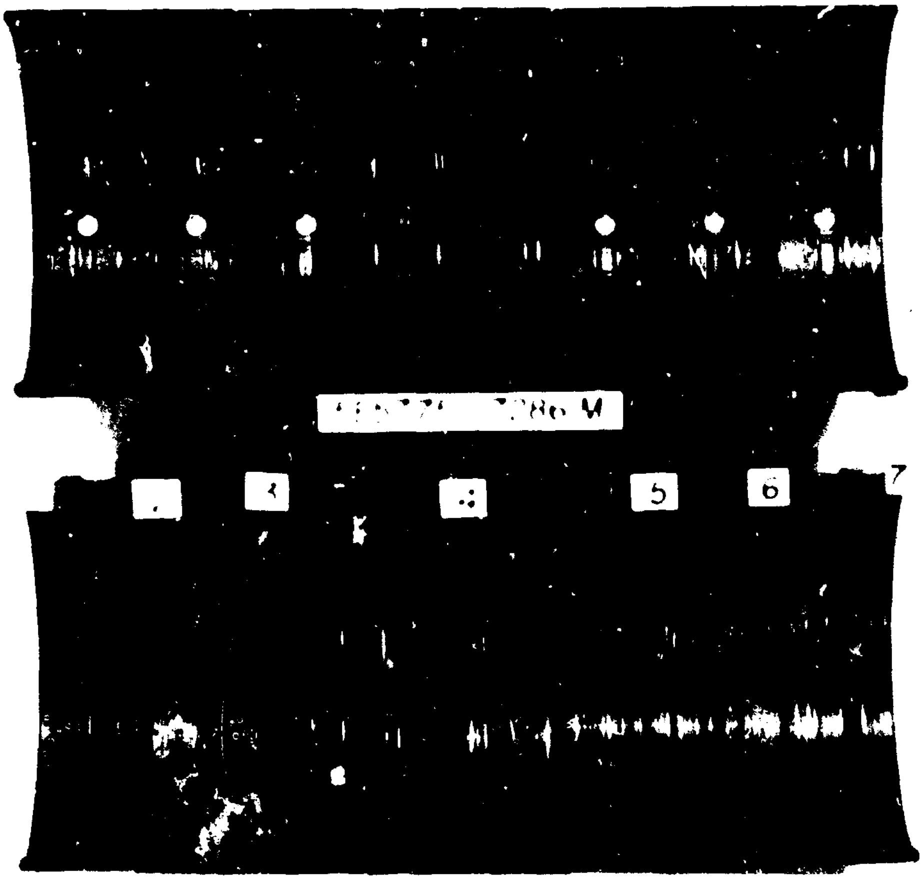

5 TON 5E-5774
CCL-O-147

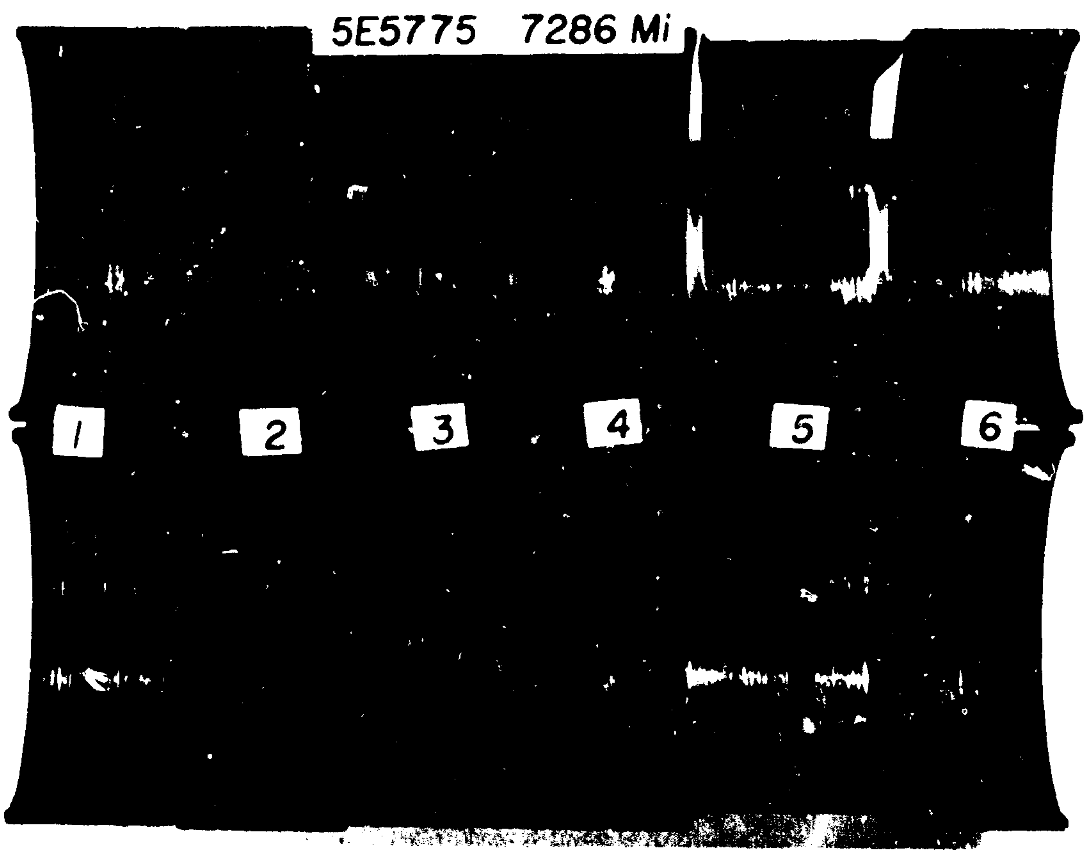

5 TON 5E-5774
CCL-O-147


5 TON 5E-5776
CCL-0-145

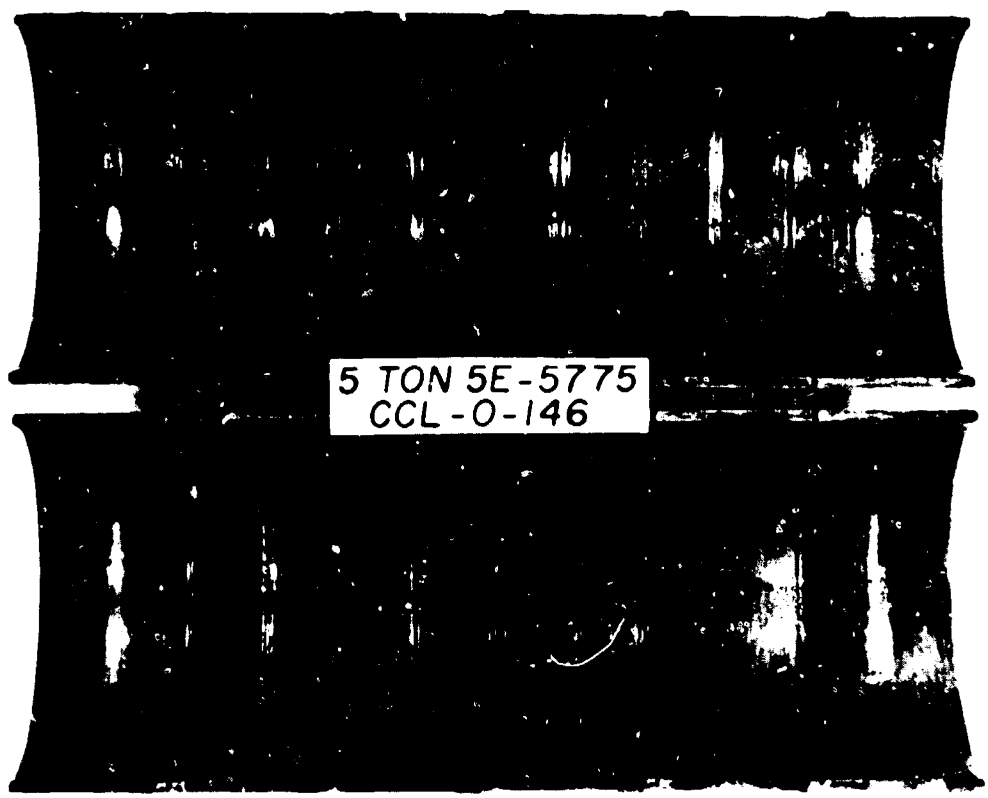

5 TON 5E-5776
CCL-0-145

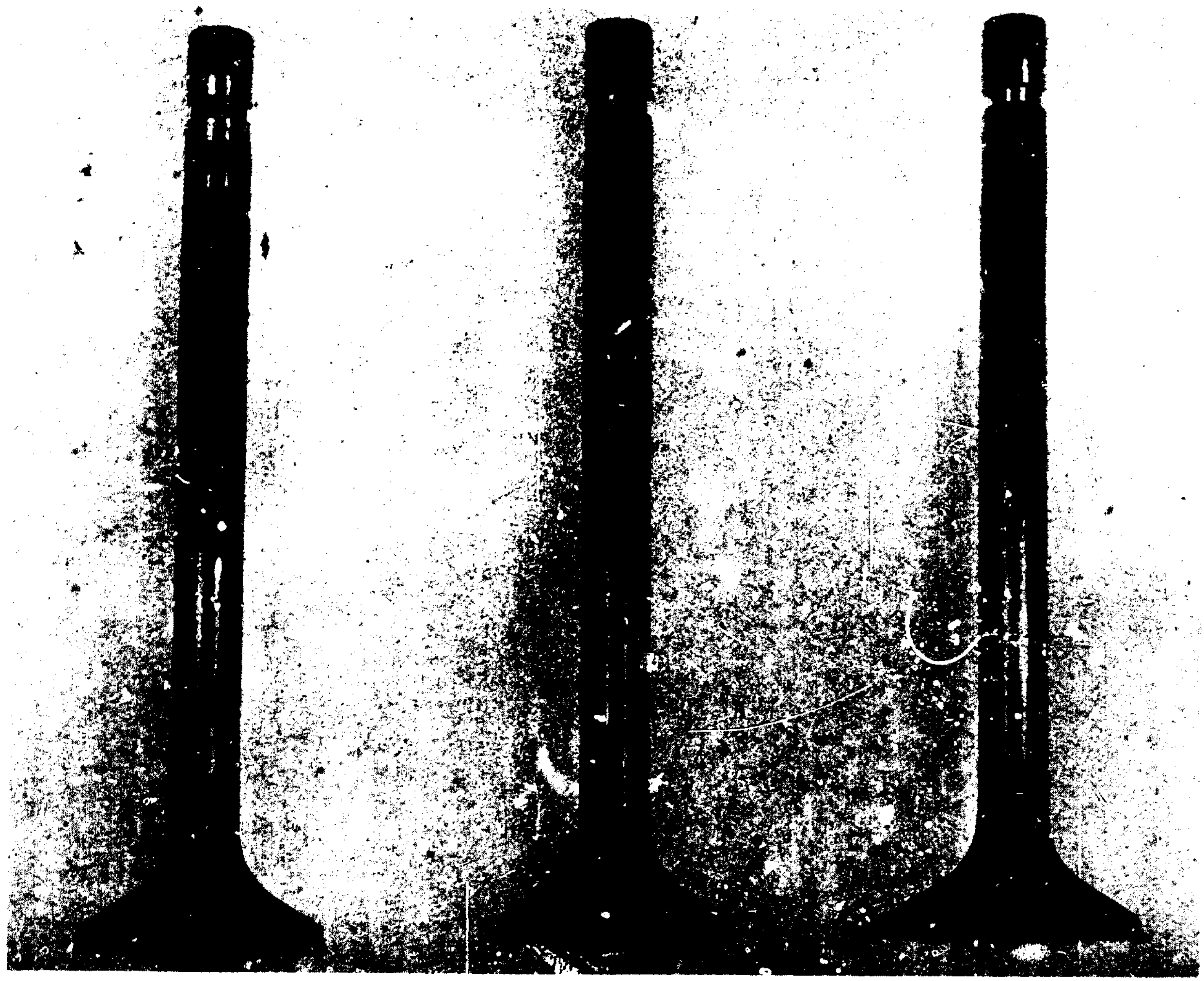
NOT REPRODUCIBLE






5 TON 5E-5775
CCL-O-146


5 TON 5E-5775
CCL-O-146



5 ton truck #5E5774, #6, 5, and 4 exhaust valves, left to right, at 10,068 miles illustrating varying degrees of valve contact face failure.

5 ton truck #5E5774 rear head at 10,068 miles. Note the exhaust valves, which originally were flush with the underside of the head, like the intake valves, have worn and pulled up into their ports. Illustration also shows cracks between valve seats.

ILLUSTRATION OF CONDITION OF TYPICAL PISTON CROWNS IN 5 TON TRUCK NO. 5E-5775

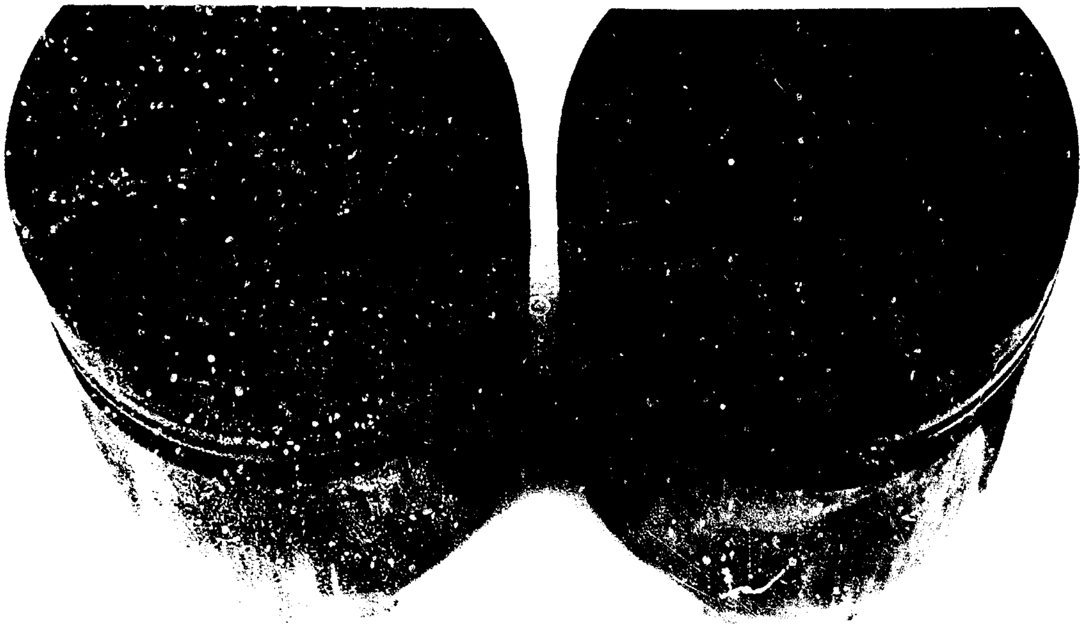
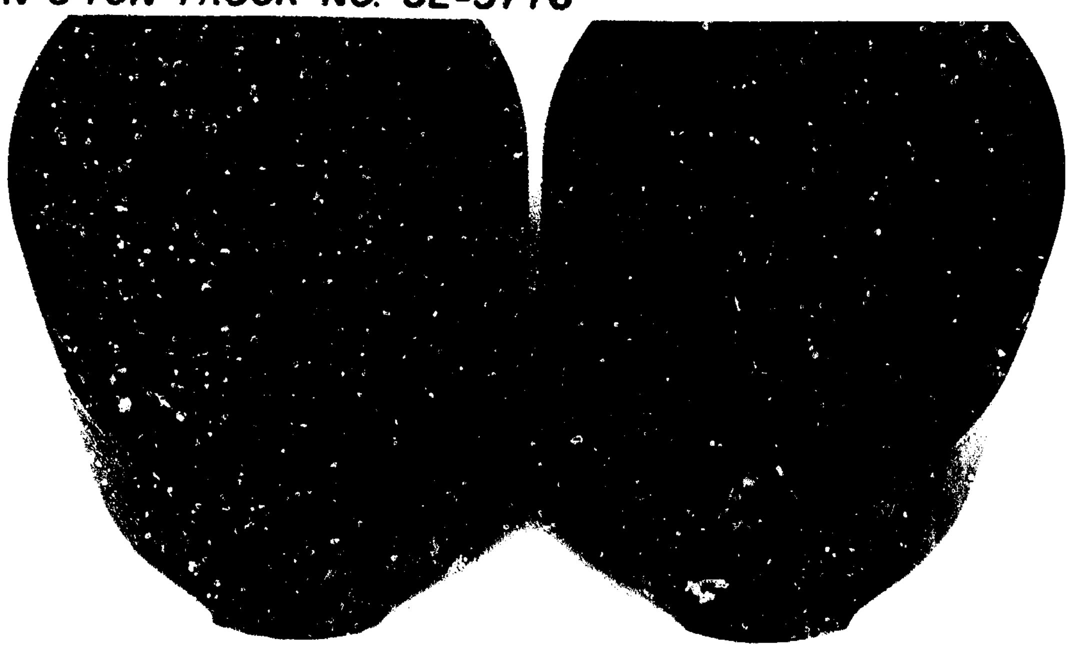
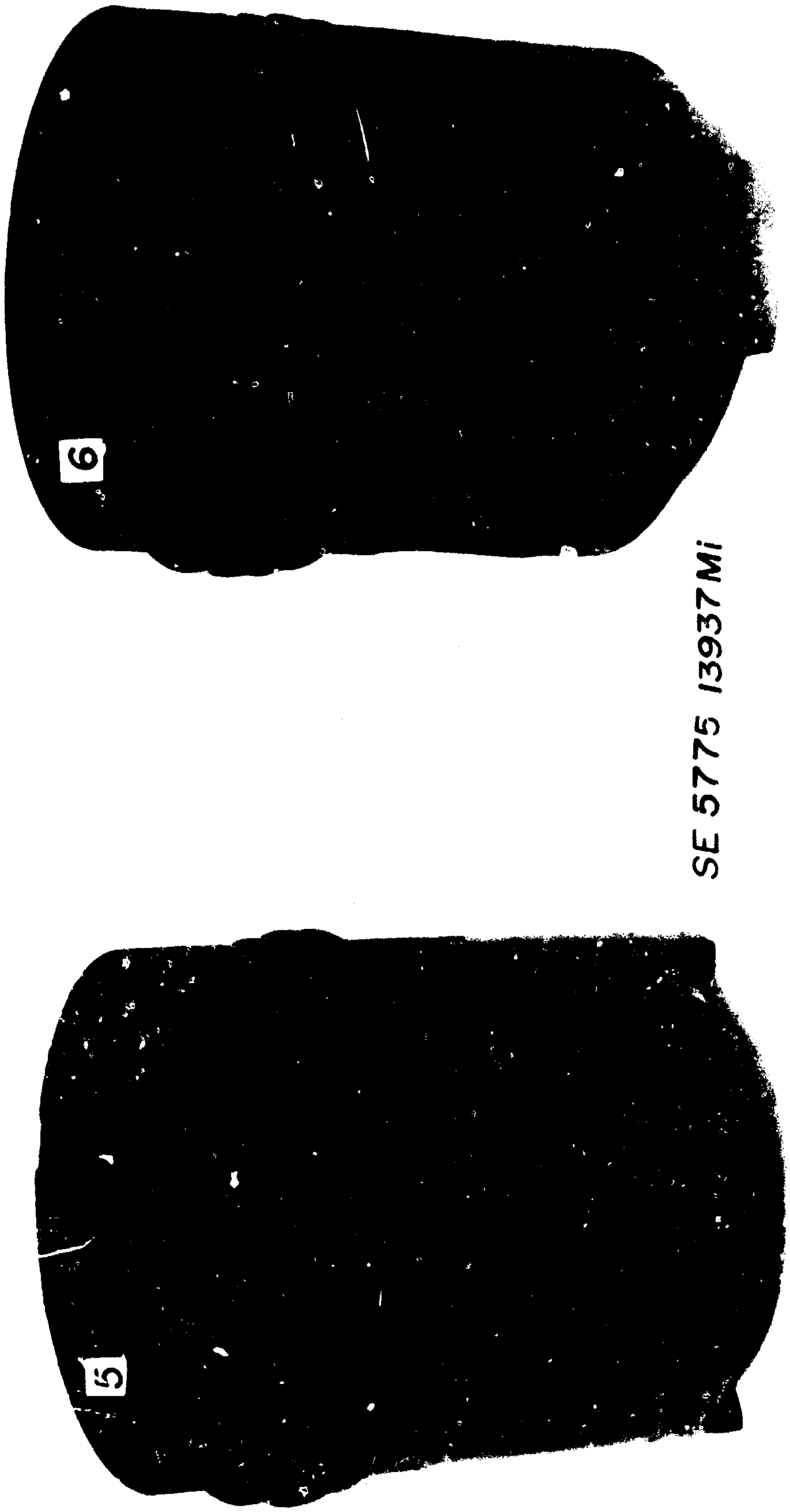


ILLUSTRATION OF CONDITION OF TYPICAL PISTON CROWNS IN 5 TON TRUCK NO. 5E-5776




6
SE 5775 13937Mi
5

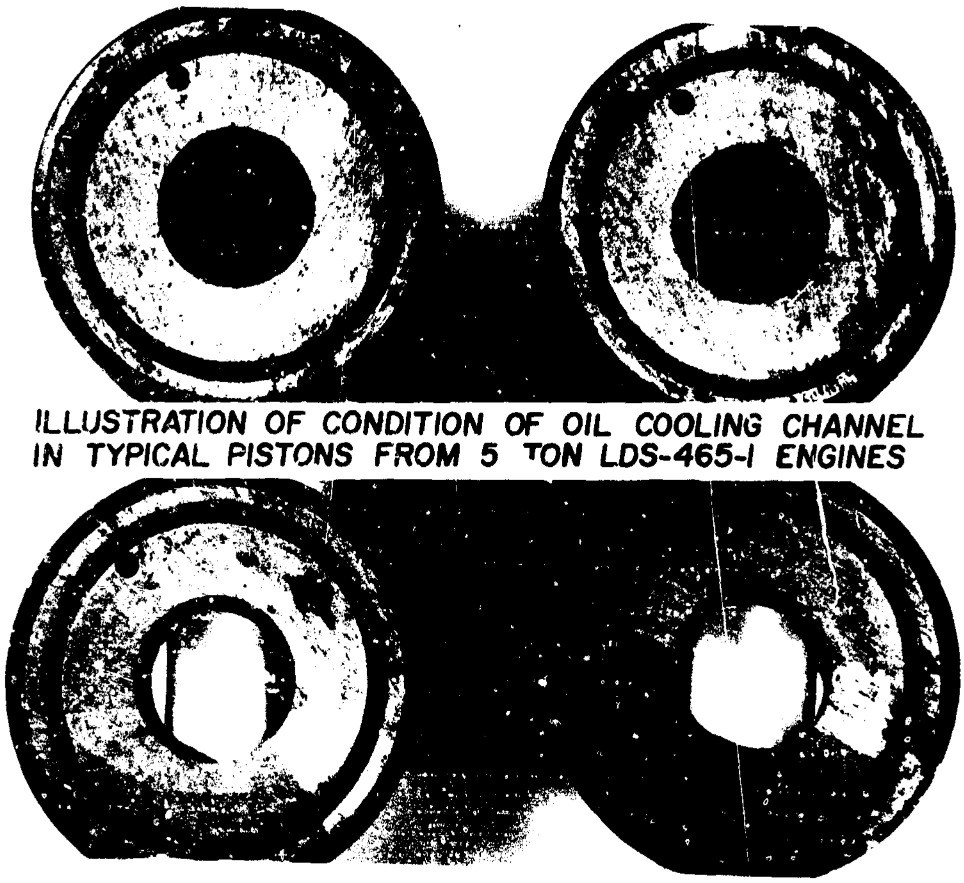
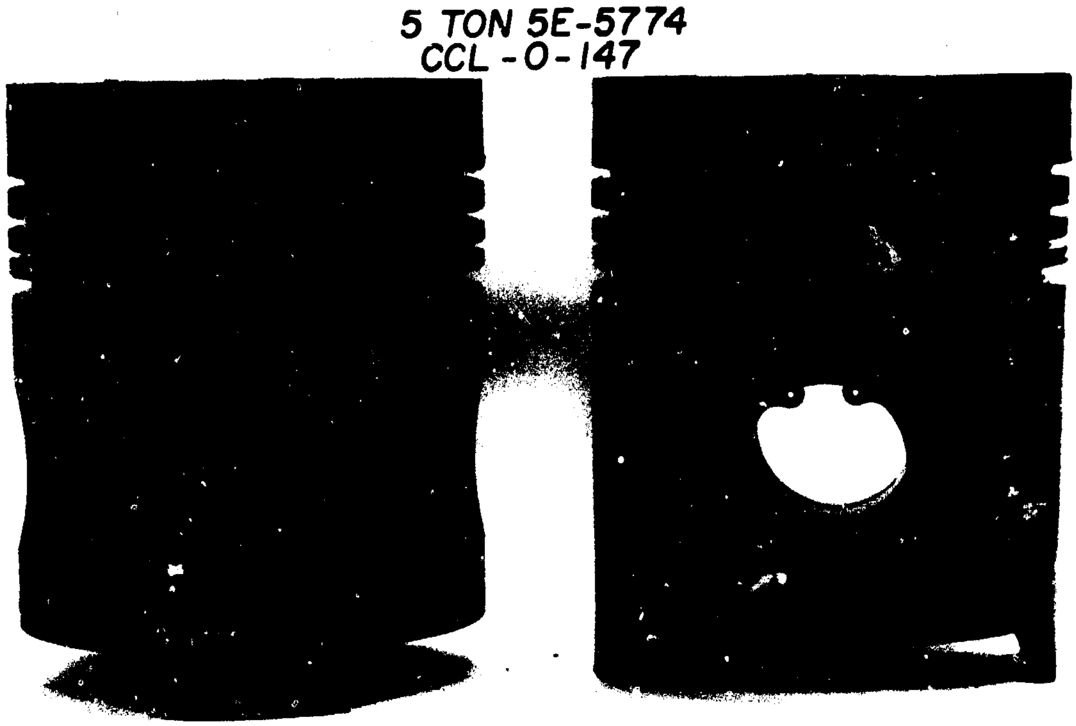
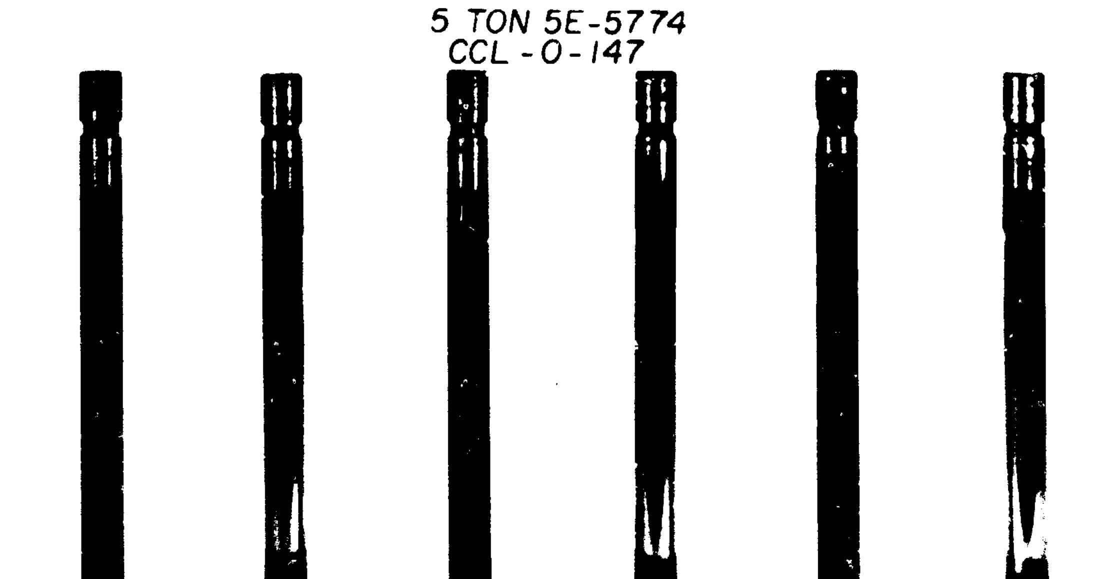


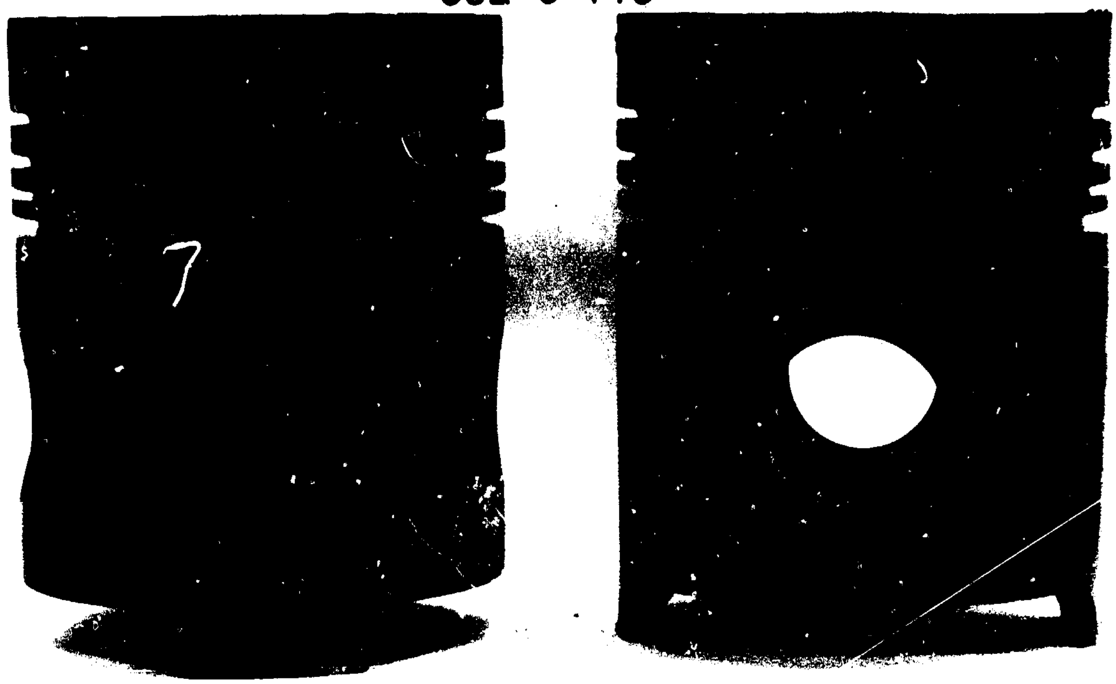
ILLUSTRATION OF CONDITION OF OIL COOLING CHANNEL
IN TYPICAL PISTONS FROM 5 TON LDS-465-1 ENGINES

CRACKED CYLINDER LINER FROM 5 TON
TRUCK NO 5E-5775 AT 13,335 MILES


5 TON 5E-5774
CCL-O-147

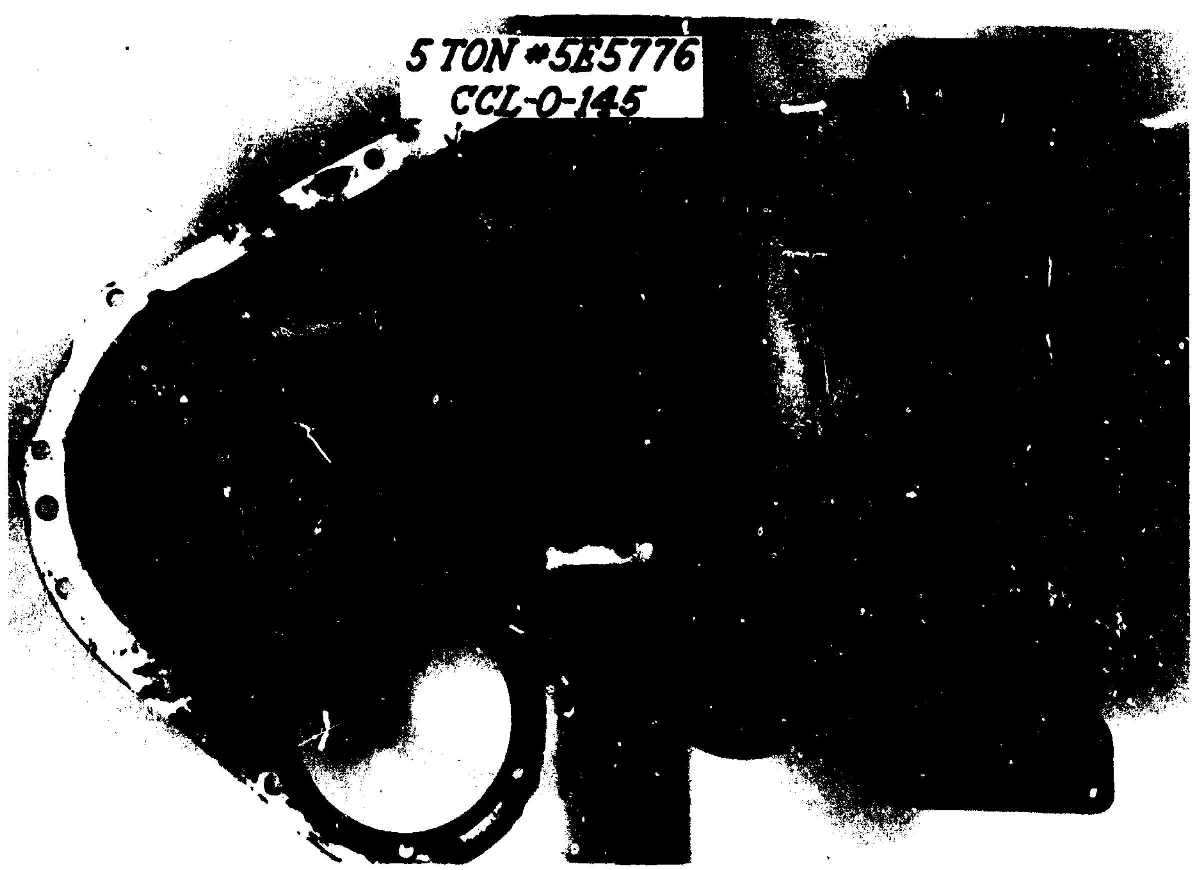

5 TON 5E-5774
CCL-O-147

5 TON 5E-5776
CCL-O-145

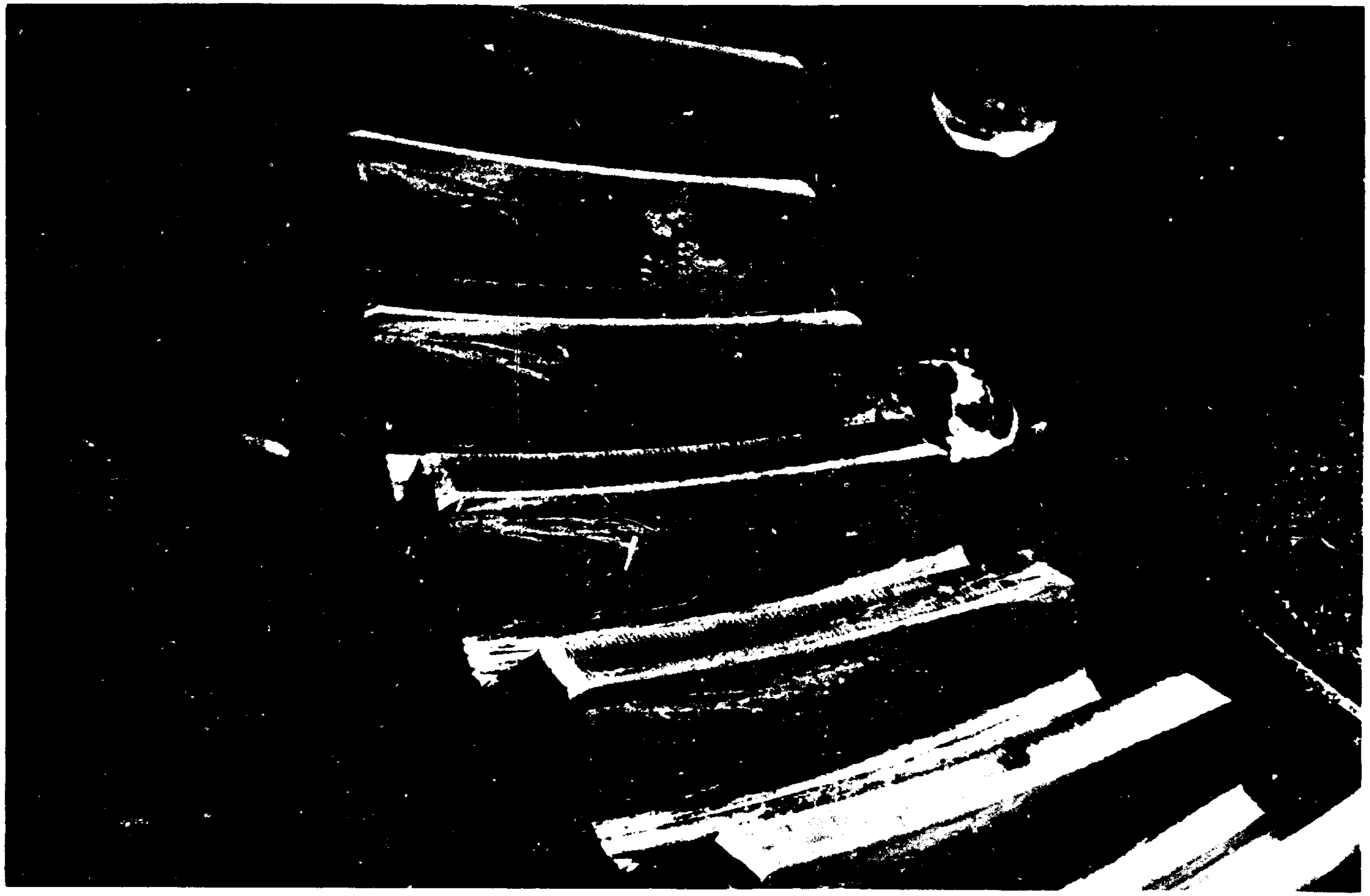


5 TON 5E-5776
CCL-O-145

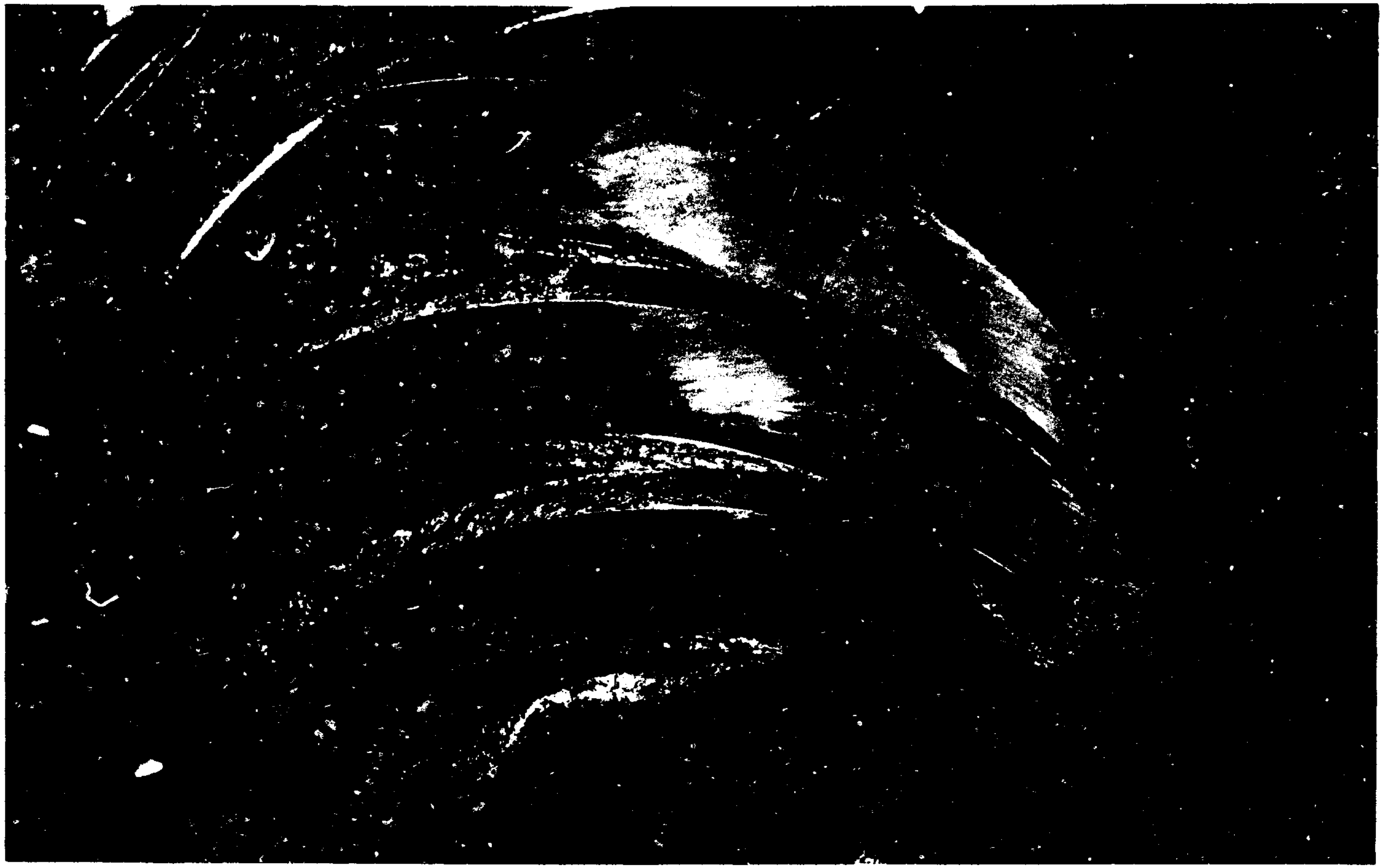

5 TON #5E5774
CCL-0-147


5 TON #5E5776
CCL-0-145

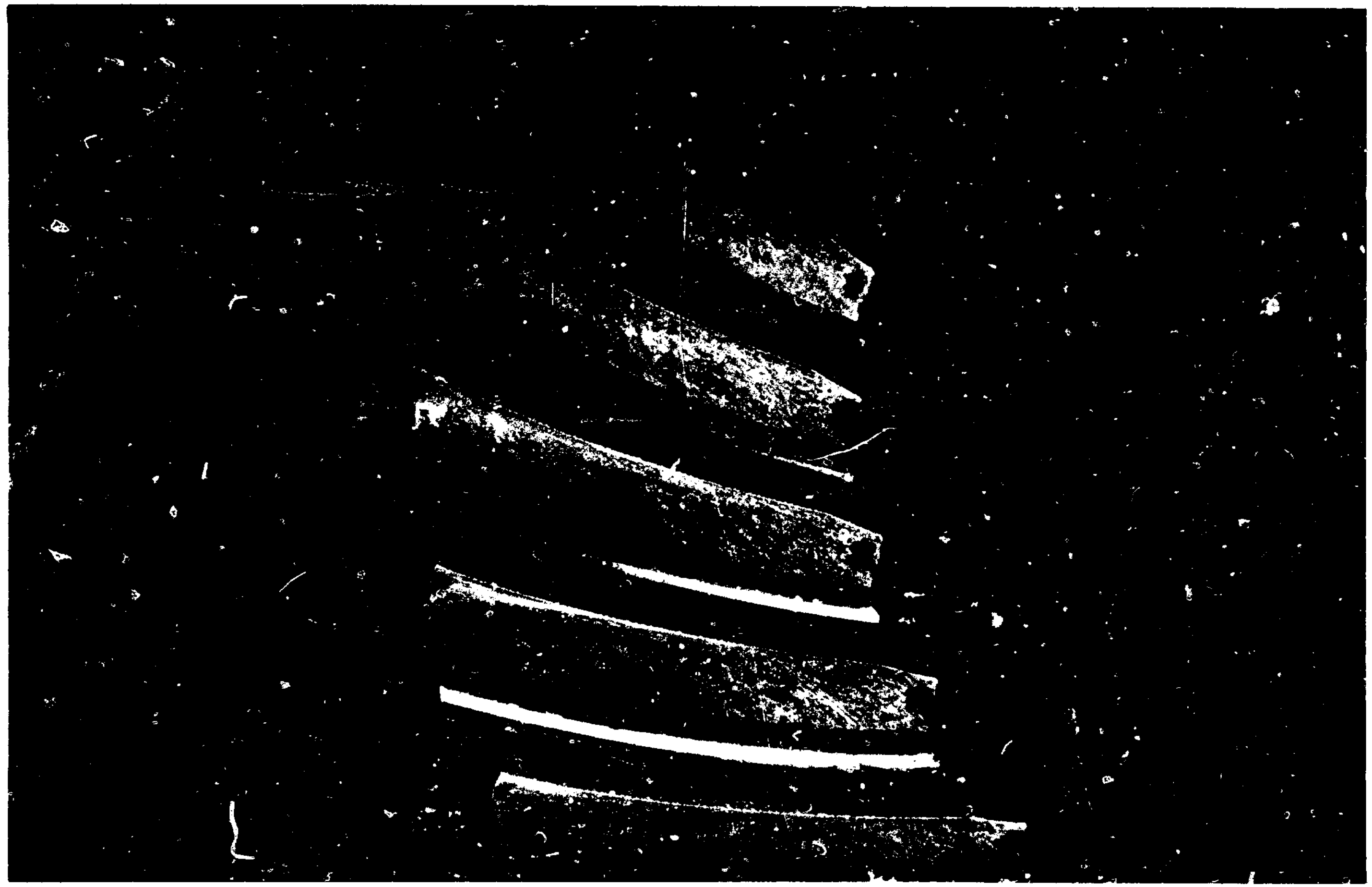
PINION GEAR, DRIVE SIDE
1/4 TON, M151 #2J8669 REAR AXLE
CCL-G-148 20,000 mi.



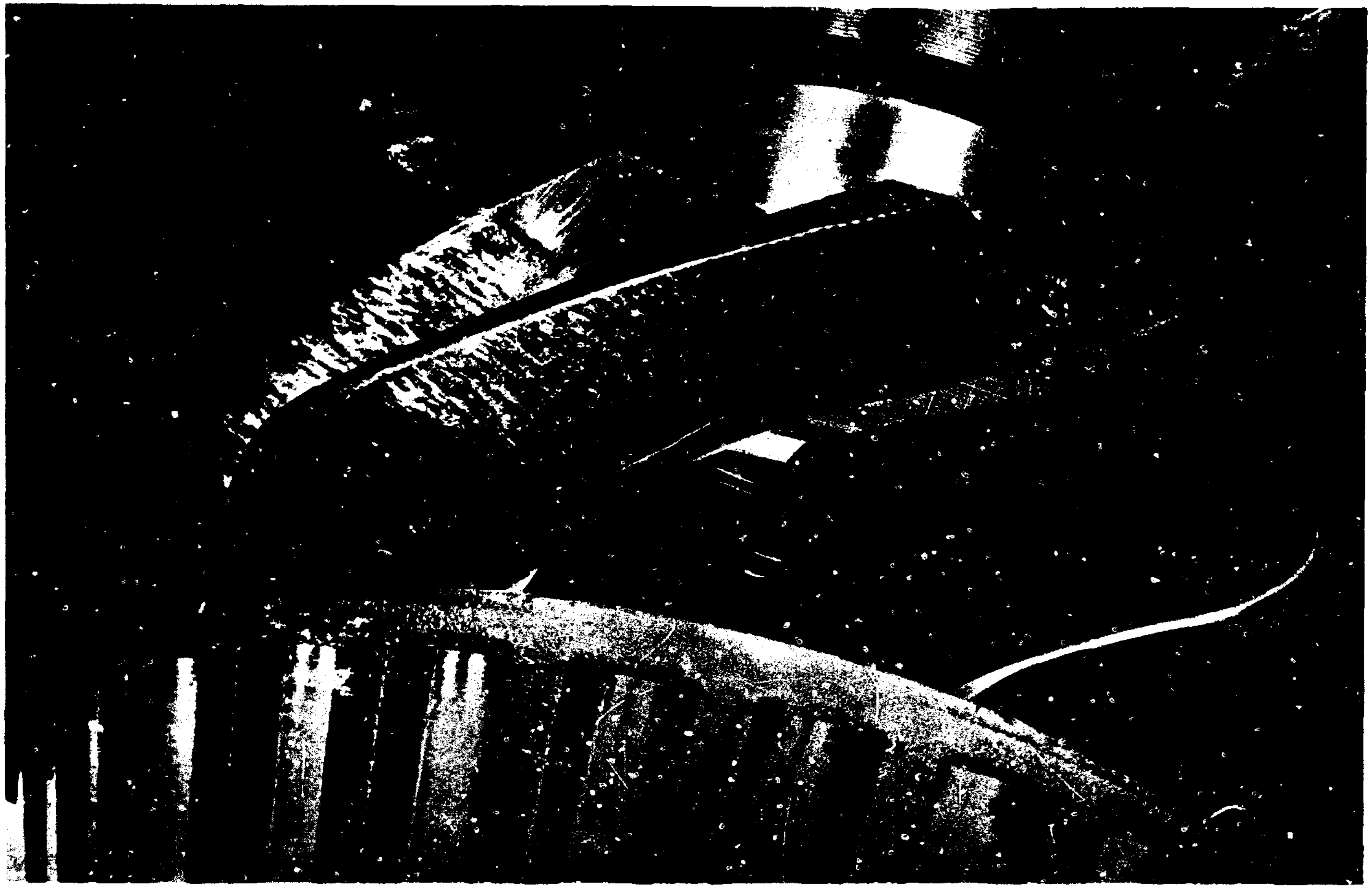
RING GEAR, DRIVE SIDE
1/4 TON, M151 #2J8669 REAR AXLE
CCL-G-148 20,000 mi.



PINION GEAR, DRIVE SIDE
3/4 TON, M37B1 #3B3632 REAR AXLE
CCL-G-148 19,058 mi.



RING GEAR, DRIVE SIDE
3/4 TON, M37B1 #3B3632 REAR AXLE
CCL-G-148 19,058 mi.



PINION GEAR, COAST SIDE
2-1/2 TON, M35A2 #4J4623 FRONT AXLE
CCL-G-151 20,000 mi.

RING GEAR, COAST SIDE
2-1/2 TON, M35A2 #4J4623 FRONT AXLE
CCL-G-151 20,000 mi.

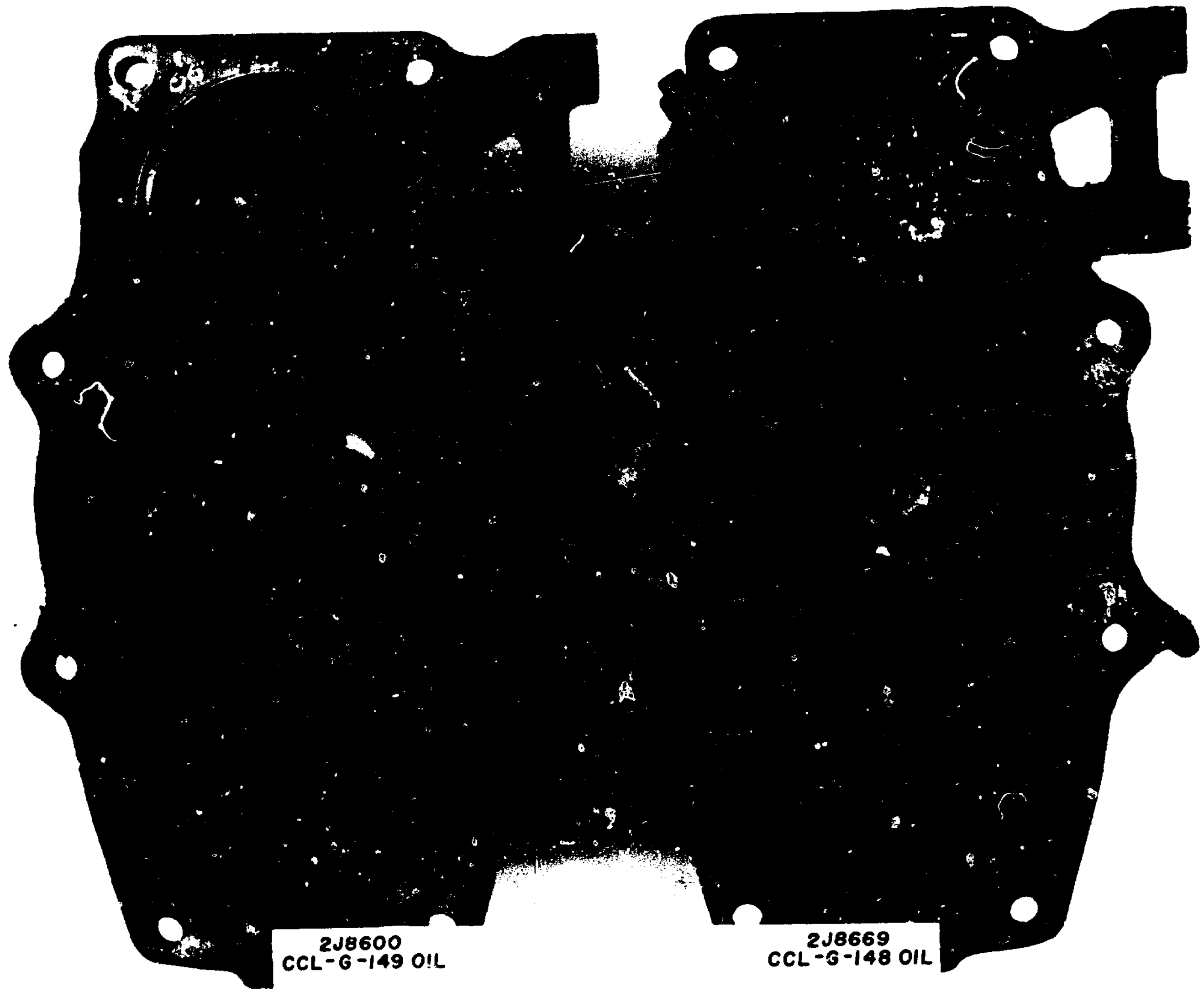
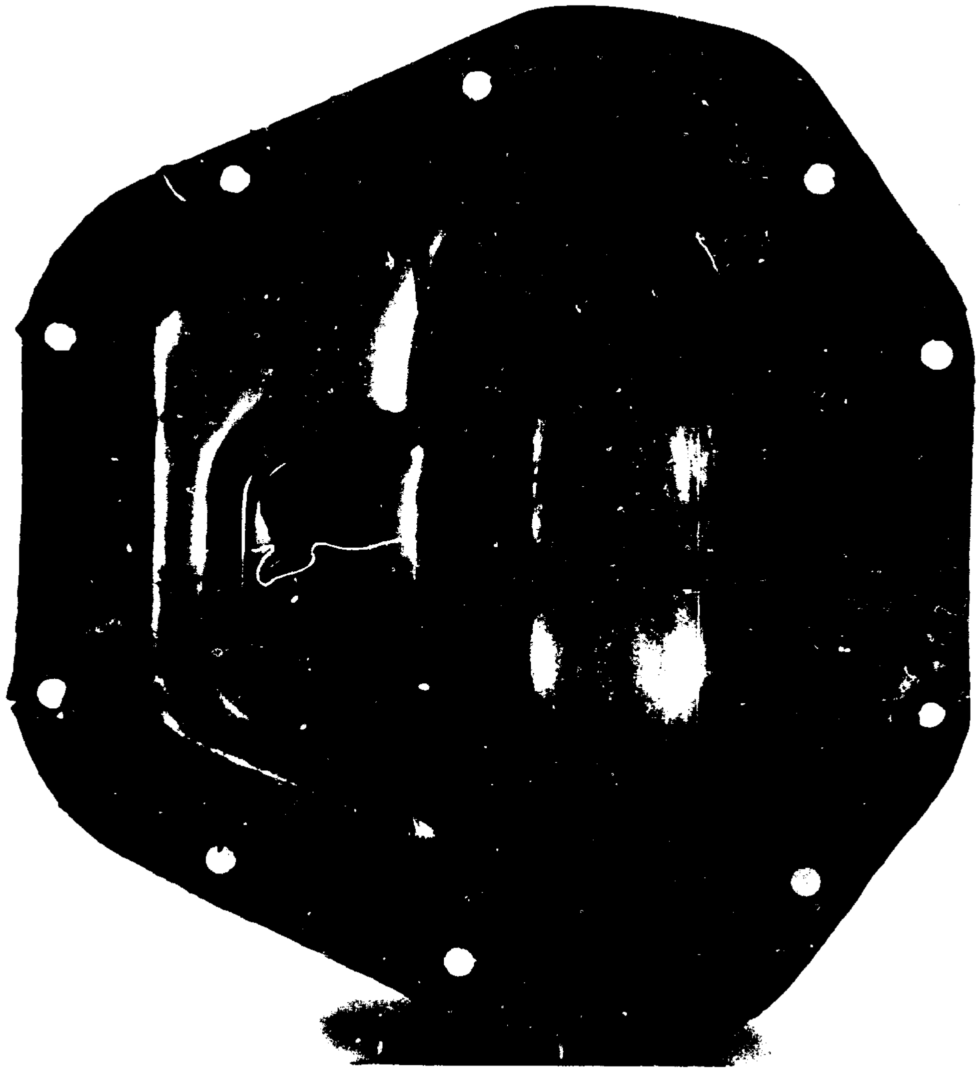
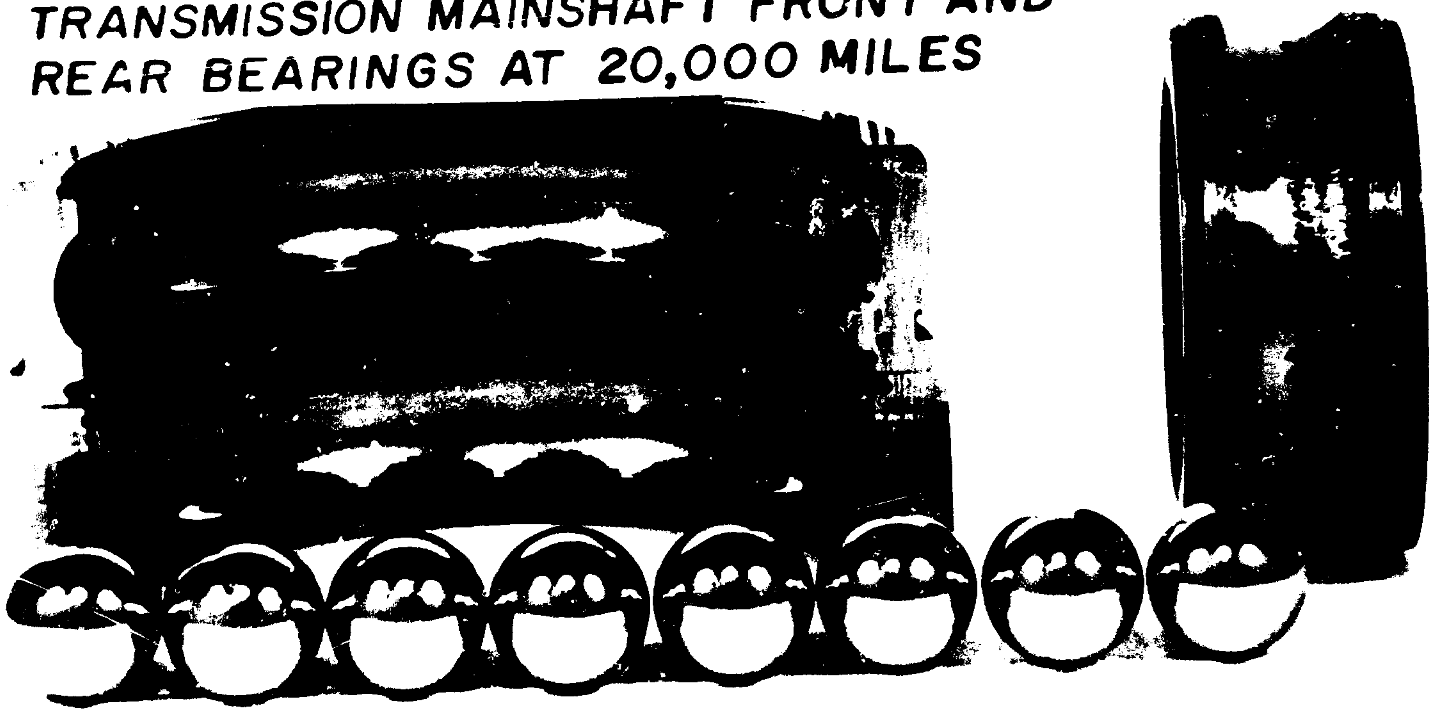


ILLUSTRATION OF THE RELATIVE CONDITION OF TWO JEEP TRANSFER CASES AT 20,000 MILES.



1 1/4 TON, M715 TRUCK # 3F3072 FRONT AXLE DIFFERENTIAL COVER ILLUSTRATING PREVALENCE OF RUSTING BELOW THE OIL LEVEL WITH CCL-G-148 LUBRICANT.



TYPICAL CONDITION OF ALL 2 1/2 TON TRANSMISSION MAINSHAFT FRONT AND REAR BEARINGS AT 20,000 MILES

APPENDICES

APPENDIX I

VEHICLE SPECIFICATIONS AND LOADINGS

VEHICLE SPECIFICATIONS AND LOADING

Truck Model	M151	Trailer Model	M416
Type	1/4-ton, 4 X 4 Truck	Type	2-Wheel
Empty Weight, lb	2425	Empty Weight	570
Highway Payload, lb	1200	Payload, lb	1430
GCW, lb	5625		
Cross-country Payload, lb	800	Payload, lb	930
Cross-country GCW, lb	4725		
Engine Model	Ord. Design (FSN 2805-678-1820)		
Cu In. Displacement	141.5		
Type and Cylinders	4 cylinders in line, O.H.V.		
Compression Ratio	7.50:1		
Fuel	Gasoline		
Transmission	4-speed Forward, Synchromesh in 2nd, 3rd, and 4th Gears		
Transfer	Single-Speed, Integral with Transmission, Manual Front Wheel Engagement		
Axle Type	Typoid		
Ratio	4.86:1		

Truck Model	M37B1	Trailer Model	M101
Type	3/4-ton, 4 X 4 Truck	Type	2-Wheel
Empty Weight, lb	5687	Empty Weight	1340
Highway Payload, lb	2000	Payload, lb	2250
GCW, lb	11,277		
Cross-country Payload, lb	1500	Payload, lb	1500
Cross-country GCW, lb	10,027		
Engine Model	Dodge T245		
Cu In. Displacement	230		
Type and Cylinders	6 cylinders, L-Head		
Compression Ratio	6.7:1		
Fuel	Gasoline		
Transmission	4-speed Forward, Synchromesh in 3rd and 4th Gears		
Transfer	2-speed, Manual Front Wheel Engagement		
Axle Type	Hypoid with Lubrited Gears		
Ratio	5.83:1		

VEHICLE SPECIFICATIONS AND LOADING (Cont'd)

Truck Model	M35A2	Trailer Model	M105
Type	2-1/2-ton, 6 X 6 Truck	Type	2-Wheel
Empty Weight, lb	13,000	Empty Weight	2750
Highway Payload, lb	10,000	Payload, lb	4500
GCW	30,250		
Cross-country Payload, lb	5,000		
Cross-country GCW, lb	18,000		
Engine Model	LD-465-1		
Cu In. Displacement	478		
Type and Cylinders	6 cylinders, O.H.V.		
Compression Ratio	22.5:1		
Fuel	Multifuel		
Transmission	5-speed		
Transfer	2-speed, Automatic Front Wheel Engagement		
Axle Type	Double Reduction		
Ratio	6.72:1		

Note:

The two-wheel M105 trailers were not towed cross-country in the sand.

Truck Model	M54A2
Type	5-ton, 6 X 6 Truck
Empty Weight, lb	19,836
Highway Payload, lb	20,000
GCW, lb	69,836
Cross-country Payload, lb	10,000
Cross-country GCW, lb	29,836
Engine Model	LDS-465-1A
Cu In. Displacement	478
Type and Cylinders	6 cylinders, O.V.H., Turbocharged
Compression Ratio	22.5:1
Fuel	Multifuel
Transmission	5-Speed
Transfer	2-speed, Automatic Front Wheel Engagement
Axle Type	Double Reduction
Ratio	6.443:1

Notes:

Pintle hook load comprised of M198A1 dolly plus commercial trailers; dolly, trailer, and trailer ballast totaled 30,000 lb during highway operation. Trailer and dolly were not towed during cross-country operation in the sand.

VEHICLE SPECIFICATIONS AND LOADING (Cont'd)

Truck Model	M54A2
Type	5-ton, 6 X 6 Truck
Empty Weight, lb	19,836
Highway Payload, lb	20,000
GCW, lb	69,836
Cross-country Payload, lb	10,000
Cross-country GCW, lb	29,836
Engine Model	LDS-465-1A
Cu In. Displacement	478
Type and Cylinders	6 cylinders, O.V.H., Turbocharged
Compression Ratio	22.5:1
Fuel	Multifuel
Transmission	5-Speed
Transfer	2-speed, Automatic Front Wheel Engagement
Axle Type	Double Reduction
Ratio	6.443:1

Notes:

Pintle hook load comprised of M198A1 dolly plus commercial trailers; dolly, trailer, and trailer ballast totaled 30,000 lb during highway operation. Trailer and dolly were not towed during cross-country operation in the sand.

APPENDIX II

SPECTROMETRIC OIL ANALYSIS DATA

Appendix II consists of Appendices I and III of the "Spectrometric Metals Analysis of Oils - Army General Purpose Vehicles," AD685886, Final Report FLRL No. 5.

TABLE 10. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 2J8600 VEHICLE TYPE 1/4 ton M151A1

CRANKCASE LUBRICANT CCL-O-145 ENGINE DESCRIPTION M151

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R.				METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT)															PHYSICAL PROPERTIES									MAKEUP OIL
	PERCENT ADDITIVE DEPLETION			OXIDATION	WEAR METALS								CONTAMINANTS			LUBRICANT ADDITIVES				MICRO-FILTRATION				SLUDGE	VISCOSITY			FUEL DILUTION	
	V.I.	DISPER.	ANTIOX.	(%)	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba	Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	AVG AGGLOMERATE SIZE (μ)	CS AT 100°F	CS AT 210°F	VIS. INDEX	(%) Vol	(LB)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	3	<1	8	1400	1500	2100	<500	0.7	0.2	0.6	1.5	0	129.5	12.6	96	0	7
64	0	0	0	0	6	230	2	<1	4	<1	<1	<5	3	<1	45	1400	1400	2100	<500	0.3	0.3	1.6	2.2	0	111.2	11.0	91.5	Tr	0
2085	32	2	30	0	30	>500	5	<1	5	<1	<1	<5	5	<1	80	1100	1300	1800	<500	0.5	0.1	1.6	2.2	6	107.4	10.0	77.5	0	0
4000	nc	nc	nc	3	65	>500	6	10	6	<1	<1	<5	5	<1	130	1200	1200	2100	<500	0.8	1.0	1.9	3.7	7	119.6	10.7	75.5	0	0
5856	nc	nc	nc	5	100	>500	8	39	26	<1	<1	<5	10	<1	130	1500	1600	2100	<500	1.1	1.6	0.8	3.5	7	121.1	10.8	75.5	0	2.2
8001	24	18	0	0	55	>500	5	35	13	<1	<1	<5	6	<1	48	1400	1600	2200	<500	0.9	0.9	1.6	3.4	7	110.5	10.4	80.0	0	0
10025	nc	nc	nc	5	62	>500	5	49	14	<1	<1	<5	6	<1	12	1300	1400	2300	<500	1.9	1.1	1.0	4.0	7	124.5	11.0	76.0	0	0
12001	nc	nc	nc	8	95	>500	7	100	20	<1	<1	<5	8	<1	30	1400	1500	2300	<500	3.8	1.4	1.1	6.3	7	135.6	11.5	74.0	Tr	0
13800	40	30	40	0	24	>500	2	20	5	<1	<1	<5	3	<1	20	1400	1500	2200	<500	1.1	0.6	1.3	3.0	7	108.8	10.4	81.5	0	0
15955	48	29	53	0	49	>500	5	42	10	<1	<1	<5	4	<1	<1	1200	1400	2400	<500	2.3	1.5	0.9	3.7	7	120.9	10.8	75.5	0	0
18093	nc	nc	nc	5	48	>500	4	40	8	<1	<1	<5	4	<1	10	1100	1400	2100	<500	3.6	1.3	0.3	5.2	7	134.8	11.4	73.0	0	2.0
20000	nc	nc	nc	8	52	>500	3	55	10	<1	<1	<5	5	<1	12	1200	1500	2100	<500	5.8	0.9	0.6	7.3	7	150.9	12.1	70.5	Tr	0

TABLE 11. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 2J8645 VEHICLE TYPE 1/4 ton M151A1

CRANKCASE LUBRICANT CCL-O-146 ENGINE DESCRIPTION M151

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	ANALYTICAL DATA: I.R. – Percent Additive Depletion: V.I.	Dispers.	Antiox.	Oxidation (%)	METAL CONCENTRATION (Expressed as parts per million by weight): Wear Metals: Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants: Si	B	Na	Lubricant Additives: P	Zn	Ca	Ba	PHYSICAL PROPERTIES: Microfiltration: Wt % > 5µ	Wt % 1.2 – 5µ	Wt % 0.22 – 1.2µ	Total Wt % > 0.22µ	Sludge: Avg Agglomerate Size (µ)	Viscosity: CS at 100°F	CS at 210°F	Vis. Index	Fuel Dilution (%) Vol	Makeup Oil (LB)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	<1	<1	10	1300	1300	2400	<500	0.4	0.3	0.7	1.4	0	120.1	12.04	97	0	7
56	0	0	0	0	26	390	<1	<1	3	<1	<1	<5	2	<1	20	1200	1100	2200	<500	0.2	0.4	0.7	1.3	0	104.6	11.2	101.0	Tr	0
2130	46	20	42	0	68	>500	5	3	5	<1	<1	<5	3	<1	40	1000	1000	2100	<500	0.4	0.6	1.7	2.7	6	109.9	11.5	100.0	0	0
4000	32	15	54	0	110	>500	6	15	7	<1	<1	<5	5	<1	55	900	1000	2100	<500	0.6	0.7	1.7	3.0	7	112.1	11.7	100.0	0	0
5802	nc	nc	nc	4	220	>500	9	100	9	<1	<1	<5	10	<1	35	1000	1200	2100	<500	1.1	0.7	1.7	3.5	14	108.3	11.3	99.0	0	1.5
7988	25	18	0	0	190	>500	7	140	24	<1	<1	<5	14	<1	40	1200	1100	2400	<500	0.9	0.8	1.9	3.6	7	107.2	11.3	99.0	0	2.2
10003	25	45	0	0	150	>500	7	140	26	<1	<1	<5	11	<1	45	800	1100	2200	<500	1.0	0.8	1.9	3.7	7	111.2	11.7	100.5	0	0
12003	nc	nc	nc	2	140	>500	4	90	12	<1	<1	<5	5	<1	35	1400	1200	2100	<500	0.9	0.4	1.0	2.3	14	106.7	11.3	100.5	Tr	8.8
13814	30	20	40	0	49	>500	3	26	4	<1	<1	<5	2	<1	18	1200	1200	2100	<500	1.0	0.5	1.1	2.6	7	108.0	11.4	100.5	2.0	0
16093	36	23	59	0	140	>500	6	70	13	<1	<1	<5	6	<1	6	1200	1300	2200	<500	1.7	0.4	1.4	3.5	14	96.3	10.6	98.5	Tr	1.9
18135	37	27	55	0	150	>500	7	82	13	<1	<1	<5	9	<1	7	1100	1200	2200	<500	1.9	1.2	2.4	5.5	14	111.6	11.7	100.3	0	2.0
20000	nc	nc	nc	4	270	>500	9	140	28	<1	<1	<16	42	<1	10	1200	1300	2100	<500	2.0	1.1	2.9	6.0	14	114.1	12.1	103.5	Tr	0

TABLE 12. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 2J8693 VEHICLE TYPE 1/4 ton M151A1

CRANKCASE LUBRICANT CCL-O-145 ENGINE DESCRIPTION M151

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion			I.R.	Metal Concentration (Expressed as parts per million by weight) — Wear Metals								Contaminants			Lubricant Additives				Physical Properties — Micro-Filtration				Sludge	Viscosity			Fuel Dilution	Makeup Oil
	V.I.	Disper.	Antiox.	Oxidation (%)	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba	Wt % > 5µ	Wt % 1.2 – 5µ	Wt % 0.22 – 1.2µ	Total Wt % > 0.22µ	Avg Agglomerate Size (µ)	CS at 100°F	CS at 210°F	Vis. Index	(%) Vol	(LB)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	3	<1	8	1400	1500	2100	<500	0.7	0.2	0.6	1.5	0	129.5	12.6	96	0	7
71	0	0	0	0	16	225	<1	<1	3	<1	<1	<5	3	<1	22	1300	1400	2100	<500	0.3	0.2	0.8	1.3	0	111.0	11.0	91.5	0.8	0
2006	46	37	12	0	67	>500	6	8	6	<1	<1	<5	7	<1	75	1200	1300	2100	<500	0.7	0.4	1.1	2.2	6	106.8	10.1	79.0	Tr	0
4000	49	49	15	0	110	>500	8	23	7	<1	<1	<5	9	<1	110	1100	1400	2100	<500	0.7	0.8	1.7	3.2	7	116.1	10.5	76.0	0	0
5802	nc	nc	nc	7	190	>500	9	70	32	<1	<1	<5	14	<1	90	1400	1500	2200	<500	1.3	1.7	1.9	4.9	5	121.6	10.7	73.5	0	0
8171	26	26	0	0	130	>500	9	70	15	<1	<1	<5	17	<1	25	1300	1400	2300	<500	0.6	1.0	1.9	3.5	7	109.4	10.7	88.0	0	1.92
10019	55	30	8	0	140	>500	12	90	20	<1	<1	<5	21	<1	12	1300	1400	2500	<500	1.2	0.9	2.0	4.1	7	115.1	10.5	76.5	0	0
11998	nc	nc	nc	3	230	>500	11	150	29	<1	<1	<5	24	<1	25	1500	1500	2400	<500	2.3	1.8	1.8	5.9	7	130.3	11.2	73.0	0	0
13807	44	18	41	0	50	>500	6	17	6	<1	<1	<5	6	<1	15	1400	1400	2200	<500	1.0	0.7	1.3	3.0	7	107.8	10.3	80.5	Tr	0
16203	46	21	41	0	82	>500	10	25	10	<1	<1	<5	7	<1	5	1200	1500	2400	<500	2.1	1.1	1.5	4.7	14	120.5	10.7	74.5	0	0
18547	43	27	48	0	95	>500	[illegible]	33	12	<1	<1	<5	9	<1	6	1400	1500	2600	<500	2.1	1.5	1.7	5.3	7	132.9	11.4	73.7	0	1.84
20000	nc	nc	nc	3	110	>500	11	34	18	<1	<1	<5	31	<1	5	1300	1700	2200	<500	2.4	2.2	1.7	6.3	7	140.8	11.9	76.0	Tr	0

TABLE 13. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 2J8666 VEHICLE TYPE 1/4 ton M151A1

CRANKCASE LUBRICANT CCL-O-144 ENGINE DESCRIPTION M151

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion: V.I.	Dispers.	Antiox.	Oxidation (%)	Metal Concentration (Expressed as parts per million by weight) Wear Metals: Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants: Si	B	Na	Lubricant Additives: P	Zn	Ca	Ba	Physical Properties Micro-Filtration: Wt % > 5µ	Wt % 1.2 – 5µ	Wt % 0.22 – 1.2µ	Total Wt % > 0.22µ	Sludge: Avg Agglomerate Size (µ)	Viscosity: CS at 100°F	CS at 210°F	Vis. Index	Fuel Dilution (%) Vol	Makeup Oil (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	9	<1	<1	800	500	950	1000	0.1	0.2	0.2	0.5	0	104.6	11.2	101	0	7
50	0	0	0	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0
2064		nc	nc	2	76	>500	8	10	5	<1	<1	<5	10	<1	60	500	350	900	1000	0.5	0.8	1.1	2.4	6	107.1	11.6	104.5	0	0
4000	nc	nc	nc	4	110	>500	9	30	6	<1	<1	<5	11	<1	90	500	450	850	1100	0.6	1.0	2.0	3.6	7	110.0	11.6	101.0	0	0
5803	nc	nc	nc	5	230	>500	12	105	40	<1	<1	30	19	<1	50	850	550	100	2200	0.9	1.1	2.0	4.0	12	109.7	11.6	100.5	0	1.9
8027	70	27	0	0	120	>500	5	65	20	<1	<1	<5	13	<1	13	650	450	950	1200	0.7	0.9	1.1	2.7	7	106.3	11.6	97.0	0	1.8
10097	nc	nc	nc	3	92	>500	5	65	20	<1	<1	<5	10	<1	<1	450	450	950	1100	0.8	0.7	1.7	3.2	7	111.5	11.7	101.0	0	0
12005	nc	nc	nc	5	150	>500	7	75	26	<1	<1	<5	14	<1	15	700	600	100	1900	1.5	1.3	2.4	5.2	14	111.9	11.7	100.5	1.0	1.7
13801	15	39	49	0	76	>500	3	23	16	<1	<1	<5	11	<1	1	800	500	950	1800	1.2	0.7	1.0	2.9	7	103.0	11.2	102.0	Tr	0
15910	nc	nc	nc	3	120	>500	6	40	22	<1	<1	<5	16	<1	1	600	550	100	1800	1.3	0.9	1.6	3.8	7	108.4	11.5	101.5	0	0
18075	nc	nc	nc	5	150	>500	7	31	24	<1	<1	<5	21	<1	7	700	500	950	2100	1.2	2.4	1.0	4.6	7	105.9	11.4	109.0	0	1.7
20000	nc	nc	nc	7	180	>500	9	37	30	<1	<1	<5	20	<1	1	700	600	950	2100	1.6	1.5	3.3	6.4	7	115.3	12.0	101.0	Tr	0

TABLE 14. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 2J8669 VEHICLE TYPE 1/4 ton M151A1

CRANKCASE LUBRICANT CCL-O-147 ENGINE DESCRIPTION M151

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	ANALYTICAL DATA: I.R. Percent Additive Depletion V.I.	I.R. Percent Additive Depletion DISPER.	I.R. Percent Additive Depletion ANTIOX.	OXIDATION (%)	METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT) Wear Metals Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants Si	B	Na	Lubricant Additives P	Zn	Ca	Ba	PHYSICAL PROPERTIES Micro-Filtration Wt % > 5µ	Wt % 1.2 – 5µ	Wt % 0.22 – 1.2µ	Total Wt % > 0.22µ	Sludge AVG AGGLOMERATE SIZE (µ)	Viscosity CS AT 100°F	CS AT 210°F	VIS. INDEX	FUEL DILUTION (%) Vol	MAKEUP OIL (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	450	400	800	800	1.0	0.1	0.1	1.2	0	110.6	10.3	78	0	7
63	0	0	0	0	14	280	2	<1	<1	<1	<1	<5	<1	<1	20	500	450	800	1250	0.1	0.0	0.0	0.1	0	100.6	9.8	80.5	1.0	0
2046	nc	nc	nc	3	42	>500	5	3	<1	<1	<1	<5	<1	<1	22	500	350	800	900	0.8	0.7	0.6	2.1	6	107.5	10.2	79.0	0	0
4000	nc	nc	nc	4	65	>500	3	7	1	<1	<1	<5	2	<1	35	500	400	800	1000	0.7	0.6	0.8	2.1	6	115.5	10.6	78.0	0	0
5940	nc	nc	nc	6	140	>500	3	36	20	<1	<1	<5	4	<1	20	600	400	800	1100	0.9	1.0	0.8	2.7	14	113.3	10.6	80.0	0	1.8
8000	0	37	0	0	92	>500	4	44	11	<1	<1	<5	3	<1	11	550	400	850	1100	0.9	0.7	0.7	2.3	7	106.6	10.2	81.0	0	0
10059	nc	nc	nc	4	82	>500	2	40	13	<1	<1	<5	2	<1	1	500	350	900	1000	1.1	0.6	0.8	2.5	>100	114.2	10.5	78.0	0	2.0
11927	nc	nc	nc	7	120	>500	3	45	11	<1	<1	<5	2	<1	10	500	400	750	900	1.7	0.8	0.9	3.4	7	122.8	11.0	78.0	1.0	0
13800	21	27	49	0	26	>500	2	10	6	<1	<1	<5	1	<1	1	550	250	750	900	1.2	0.4	0.4	2.0	>100	105.1	10.1	80.0	0	0
16095	nc	nc	nc	3	35	>500	1	11	1	<1	<1	<5	1	<1	1	350	250	700	600	1.0	0.4	0.4	1.8	>100	88.5	9.2	83.0	0	0
17977	nc	nc	nc	6	42	>500	1	18	1	<1	<1	<5	1	<1	1	300	200	700	<500	1.7	0.6	5.4	7.7	7	123.2	11.1	78.2	1.0	0
18991	nc	nc	nc	7	55	>500	1	21	2	<1	<1	<5	1	<1	1	350	250	700	<500	2.1	0.6	0.6	3.3	7	121.0	11.4	86.6	0	0
20000	nc	nc	nc	8	54	>500	1	11	2	<1	<1	<5	12	<1	1	350	250	500	600	2.3	0.3	0.6	3.2	14	123.9	12.9	105.5	Tr	0

TABLE 15. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 3B3632 VEHICLE TYPE 3/4 ton M37B1

CRANKCASE LUBRICANT CCL-O-146 ENGINE DESCRIPTION Dodge T245

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	I.R. Percent Additive Depletion V.I.	I.R. Percent Additive Depletion DISPER.	I.R. Percent Additive Depletion ANTIOX.	I.R. OXIDATION (%)	Wear Metals Fe	Wear Metals Pb	Wear Metals Cu	Wear Metals Cr	Wear Metals Al	Wear Metals Ni	Wear Metals Ag	Wear Metals Sn	Contaminants Si	Contaminants B	Contaminants Na	Lubricant Additives P	Lubricant Additives Zn	Lubricant Additives Ca	Lubricant Additives Ba	Micro-Filtration Wt % > 5μ	Micro-Filtration Wt % 1.2 – 5μ	Micro-Filtration Wt % 0.22 – 1.2μ	Micro-Filtration Total Wt % > 0.22μ	Sludge Avg Agglomerate Size (μ)	Viscosity CS at 100°F	Viscosity CS at 210°F	Vis. Index	Fuel Dilution (%) Vol	Makeup Oil (LB)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	3	<1	8	1300	1300	2400	<500	0.4	0.3	0.7	1.4	0	120.1	12.01	97	0	–
67	0	0	0	0	25	310	2	1	4	<1	<1	34	2	<1	20	1300	1300	1900	<500	0.4	0.3	1.0	1.7	0	109.8	11.5	100.0	0	0
2000	50	18	36	0	76	>500	11	2	11	<1	<1	32	4	<1	15	1400	1200	2400	<500	0.6	0.5	1.1	2.2	7	117.2	12.0	99.0	2.0	15.3
4057	nc	nc	nc	4	120	>500	12	8	25	<1	<1	33	5	<1	35	1400	1200	2900	<500	0.7	0.8	1.7	3.2	5	111.7	11.7	101.0	0	13.2
5807	nc	nc	nc	6	150	>500	12	15	30	<1	<1	25	4	<1	25	1600	1400	2800	<500	1.2	1.0	1.3	3.5	10	111.6	11.6	100.0	0	12.0
8118	27	22	0	0	140	>500	8	32	24	<1	<1	22	8	<1	25	1300	1100	2500	<500	0.7	0.9	2.1	3.7	7	120.2	12.3	101.5	3.0	8.9
9942	30	32	10	0	160	>500	11	54	28	<1	<1	24	6	<1	20	1300	1300	2500	<500	0.8	0.8	2.6	4.2	7	nd	nd	nd	nd	4.2
12000	24	36	45	0	240	>500	17	110	41	<1	<1	<5	8	<1	40	1500	1500	2500	<500	1.0	1.1	2.8	4.9	7	122.4	12.4	99.5	1.0	5.1
13800	29	28	52	0	130	>500	8	50	16	<1	<1	14	3	<1	35	1400	1500	2400	<500	1.1	0.4	1.5	3.0	7	110.6	11.5	99.5	3.0	7.2
16017	31	27	49	0	270	>500	17	100	44	<1	<1	21	9	<1	35	1400	1600	2800	<500	2.1	1.2	2.5	5.8	7	111.7	11.6	99.0	0	1.8
18056	30	28	46	0	290	>500	20	74	50	<1	<1	35	10	<1	25	1300	1700	2900	<500	1.4	1.4	3.3	6.1	7	121.5	12.3	99.0	0	5.3
19058	45	31	51	0	220	>500	6	16	30	<1	<1	25	8	<1	45	1500	1400	2200	<500	1.7	0.7	1.5	3.9	7	122.8	11.6	88.5	Tr	4.4

TABLE 16. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 3G6207 VEHICLE TYPE 3/4 ton M37B1

CRANKCASE LUBRICANT CCL-O-144 ENGINE DESCRIPTION Dodge T245

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	ANALYTICAL DATA																												MAKEUP OIL
	I.R.				METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT)															PHYSICAL PROPERTIES									
	PERCENT ADDITIVE DEPLETION			OXIDATION	WEAR METALS								CONTAMINANTS			LUBRICANT ADDITIVES				MICRO-FILTRATION				SLUDGE	VISCOSITY			FUEL DILUTION	
	V.I.	DISPER.	ANTIOX.	(%)	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba	Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	AVG AGGLOMERATE SIZE (μ)	CS AT 100°F	CS AT 210°F	VIS. INDEX	(%) Vol	(LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	9	<1	<1	800	500	950	1000	0.1	0.2	0.2	0.5	0	104.6	11.2	101	0	–
49	0	0	0	0	120	>500	13	2	11	<1	<1	30	20	<1	6	1100	450	900	1100	0.3	0.3	0.7	1.3	0	97.0	10.8	104.0	Tr	0
2047	nc	3	7	0	290	>500	24	21	25	<1	<1	52	24	<1	8	850	450	1000	2100	0.8	0.8	1.8	3.4	7	113.9	11.9	100.5	2.0	3.5
3900	nc	nc	nc	3	400	>500	28	56	50	<1	<1	45	28	<1	7	800	550	950	2100	1.6	1.6	3.0	6.2	7	113.1	11.9	102.0	1.0	3.7
5793	nc	nc	nc	5	380	>500	19	44	42	2	<1	30	26	<1	12	800	500	1100	2300	1.0	1.1	1.4	3.5	14	109.8	11.5	100.5	0	5.0
8080	0	50	0	0	240	>500	12	9	22	<1	<1	<5	16	<1	1	700	450	1000	1700	0.6	0.7	0.7	2.0	7	102.4	11.2	102.5	0	2.8
10050	nc	nc	nc	6	510	>500	15	22	31	<1	<1	15	27	<1	5	900	500	1000	2000	1.2	0.7	2.0	3.9	>100	109.6	11.8	104.0	0	5.2
12001	nc	nc	nc	8	860	>500	18	30	41	<1	<1	15	35	<1	10	950	600	1200	2600	1.9	1.1	2.7	5.7	>100	109.6	11.6	102.0	2.0	11.1
13800	18	43	50	0	250	>500	8	6	25	<1	<1	<5	15	<1	1	1100	650	1200	2600	1.9	0.7	1.0	3.6	7	106.3	11.4	102.5	0	10.9
16081	nc	nc	nc	3	340	>500	13	12	52	<1	<1	<5	20	7	25	900	650	1300	2500	2.1	1.2	1.7	5.0	7	106.7	11.4	102.0	0	8.8
17942	nc	nc	nc	4	300	>500	9	4	32	<1	<1	<5	42	<1	1	800	600	1100	1800	1.5	0.5	0.7	2.7	14	106.5	11.5	103.0	Tr	22.7
20000	nc	nc	nc	6	390	>500	9	5	40	<1	<1	<5	21	<1	1	950	800	1400	3100	2.8	0.9	1.5	5.2	14	103.0	11.3	104.0	0	17.5

TABLE 17. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 3F3183 VEHICLE TYPE 1-1/4 ton M715

CRANKCASE LUBRICANT CCL-O-144 ENGINE DESCRIPTION 6-230

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. PERCENT ADDITIVE DEPLETION V.I.	DISPER.	ANTIOX.	OXIDATION (%)	METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT) WEAR METALS Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	CONTAMINANTS Si	B	Na	LUBRICANT ADDITIVES P	Zn	Ca	Ba	PHYSICAL PROPERTIES MICRO-FILTRATION Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	SLUDGE AVG AGGLOMERATE SIZE (μ)	VISCOSITY CS AT 100°F	CS AT 210°F	VIS. INDEX	FUEL DILUTION (%) Vol	MAKEUP OIL (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	9	<1	<1	800	500	950	1000	0.1	0.2	0.2	0.5	0	104.6	11.2	101	0	-
50	0	0	0	0	17	280	62	<1	2	<1	<1	<5	10	<1	25	850	400	1000	1100	0.5	0.8	1.6	2.9	0	95.9	10.7	103.0	0	3.4
1999	nc	10	10	0	170	>500	15	3	6	<1	<1	<5	11	<1	20	600	450	950	1200	0.6	0.6	1.3	2.5	5	110.4	11.7	102.0	0	3.4
4000	nc	nc	nc	2	200	>500	21	10	9	<1	<1	<5	14	<1	35	700	450	1100	1900	0.5	0.5	1.2	2.2	6	114.8	12.0	101.0	0	12.0
5801	nc	nc	nc	4	200	>500	19	13	20	<1	<1	<5	19	<1	20	900	600	1100	2100	0.9	2.5	0.7	4.1	10	110.6	11.8	94.0	0	1.8
8290	nc	nc	nc	4	150	>500	10	14	9	<1	<1	<5	8	<1	10	500	450	1000	1100	1.0	1.4	1.9	4.3	7	107.0	11.7	105.0	0	3.6
10018	nc	nc	nc	8	160	>500	13	25	10	<1	<1	<5	8	<1	7	600	500	1000	1900	0.6	0.5	2.0	3.1	7	113.4	11.9	101.5	0	5.7
12177	nc	nc	nc	9	140	>500	14	40	10	<1	<1	<5	7	<1	1	600	550	1100	1500	1.3	1.3	2.7	5.3	7	109.3	11.6	101.0	0	7.3
16000	nc	nc	nc	4	180	>500	10	52	12	<1	<1	<5	9	<1	3	900	600	1200	2200	1.6	0.8	2.0	4.4	7	114.9	12.0	101.5	0	3.6
17973	nc	nc	nc	7	190	>500	9	48	15	<1	<1	<5	7	<1	1	700	650	1100	2700	1.5	1.2	2.8	5.5	7	124.8	12.3	96.0	0	5.9
20000	nc	nc	nc	8	180	>500	9	44	12	<1	<1	<5	8	<1	10	850	650	1100	2800	2.7	3.0	2.4	8.1	7	110.5	11.7	102.5	0	4.2

TABLE 18. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 3F3078 VEHICLE TYPE 1-1/4 ton M715

CRANKCASE LUBRICANT CCL-O-146 ENGINE DESCRIPTION 6-230

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	ANALYTICAL DATA: I.R. Percent Additive Depletion V.I.	I.R. Percent Additive Depletion DISPER.	I.R. Percent Additive Depletion ANTIOX.	OXIDATION (%)	Metal Concentration (expressed as parts per million by weight) Wear Metals Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants Si	B	Na	Lubricant Additives P	Zn	Ca	Ba	Physical Properties Micro-Filtration Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	Sludge Avg Agglomerate Size (μ)	Viscosity cS at 100°F	cS at 210°F	Vis. Index	Fuel Dilution (%) Vol	Makeup Oil (LB)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	<1	<1	10	1300	1300	2400	<500	0.1	0.4	1.0	1.5	0	120.1	12.0	97	0	–
51	0	0	0	0	26	460	2	4	4	<1	<1	<5	3	<1	35	1300	1100	2400	<500	0.3	0.3	0.8	1.4	0	109.9	11.5	99.0	0	0
2000	48	25	39	0	27	>500	17	1	10	<1	<1	<5	3	78	350	1200	1100	2600	<500	0.5	0.6	1.1	2.2	7	118.3	12.2	101.0	0	[illegible]
4009	53	48	59	0	56	>500	20	3	9	<1	<1	<5	8	100	550	1100	1200	2500	<500	1.0	0.9	1.8	3.7	5	123.3	12.5	100.0	0	9.1
5799	nc	nc	nc	4	97	>500	17	8	16	<1	<1	<5	14	89	600	1500	1300	2900	<500	0.3	0.4	1.0	1.7	5	120.6	12.3	100.[illegible]	0	8.9
8195	27	40	0	0	65	>500	10	5	7	<1	<1	<5	4	<3	100	1700	1600	2300	<500	0.7	0.6	1.2	2.5	7	130.7	13.4	105.0	0	3.5
10001	30	43	0	0	72	>500	8	6	9	<1	<1	<5	4	1	65	1400	1400	2400	<500	0.8	0.5	1.4	2.7	7	128.6	12.8	100.0	Tr	7.0
11935	31	23	60	0	95	>500	9	14	13	<1	<1	<5	6	3	95	1200	1600	2500	<500	0.8	0.6	1.8	3.2	7	127.6	12.7	99.5	1.5	5.3
13800	27	18	45	0	50	>500	5	5	7	<1	<1	<5	7	14	200	1300	1300	2500	<500	1.2	0.6	1.1	2.9	14	115.2	11.9	100.0	1.0	10.5
16010	31	18	42	0	100	>500	11	14	12	<1	<1	<5	8	32	400	1200	1300	2600	<500	0.9	0.4	1.2	2.5	7	122.9	12.6	102.0	0	5.4
18138	32	21	59	0	120	>500	10	23	17	<1	<1	<5	13	33	300	1200	1400	2800	<500	1.4	1.3	1.2	3.9	7	123.3	12.5	100.5	0	8.0
20000	32	23	58	0	150	>500	10	25	26	<1	<1	<5	16	50	510	1400	1500	2800	<500	2.4	1.1	2.1	5.6	7	117.6	12.1	101.0	0	4.9

TABLE 19. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 3F3199 VEHICLE TYPE 1-1/4 ton M715

CRANKCASE LUBRICANT CCL-O-145 ENGINE DESCRIPTION 6-230

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	ANALYTICAL DATA																												
	I.R.				METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT)															PHYSICAL PROPERTIES									MAKEUP OIL (LB)
	PERCENT ADDITIVE DEPLETION			OXIDATION (%)	WEAR METALS								CONTAMINANTS			LUBRICANT ADDITIVES				MICRO-FILTRATION				SLUDGE	VISCOSITY			FUEL DILUTION (%) Vol	
	V.I.	DISPER.	ANTIOX.		Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba	Wt % > 5µ	Wt % 1.2 – 5µ	Wt % 0.22 – 1.2µ	Total Wt % > 0.22µ	AVG AGGLOMERATE SIZE (µ)	CS AT 100°F	CS AT 210°F	VIS. INDEX		
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	3	<1	8	1400	1500	2100	<500	0.6	0.1	0.7	1.4	0	129.5	12.6	56	0	--
63	0	0	0	0	30	305	8	<1	3	<1	<1	<5	5	<1	110	1300	1300	2500	<500	0.3	0.3	1.2	1.8	0	89.1	9.8	96.0	0.7	0
1023	-	-	-	-	130	>500	16	1	6	<1	<1	<5	6	<1	80	1600	1300	2100	<500	nd	nd	nd	nd	5	nd	nd	nd	nd	1.9
3000	36	10	36	0	190	>500	19	2	10	<1	<1	<5	7	<1	80	1600	1600	2600	<500	0.3	0.2	0.9	1.4	7	115.9	10.7	79.0	0	10.2
4023	46	23	52	0	130	>500	16	1	6	<1	<1	<5	6	<1	80	1600	1300	2100	<500	0.8	1.6	1.5	3.9	7	114.3	10.6	80.0	0	3.9
5800	nc	nc	nc	4	170	>500	15	3	15	<1	<1	<5	8	<1	60	1800	1600	3000	<500	2.0	2.2	3.8	8.0	7	118.1	10.9	80.5	0	8.5
7989	16	19	0	0	95	>500	9	1	9	<1	<1	<5	4	<1	30	1500	1700	2600	<500	0.8	1.3	2.0	4.1	7	120.3	10.8	75.5	1.0	11.5
10602	15	30	15	0	110	>500	10	4	12	<1	<1	<5	4	<1	15	1500	1700	2800	<500	1.2	1.1	2.0	4.3	7	130.8	11.4	76.0	0	10.0
12143	36	30	42	0	150	>500	14	9	19	<1	<1	<5	5	<1	12	1600	2100	3100	<500	1.8	1.6	2.1	5.5	7	141.5	12.0	76.0	Tr	3.5
13667	38	22	44	0	65	>500	6	4	7	<1	<1	<5	4	15	75	1400	1600	2400	<500	1.5	0.7	1.5	3.7	7	nd	nd	nd	nd	5.7
16042	34	22	43	0	140	>500	10	13	12	<1	<1	<5	6	7	25	1600	1700	2900	<500	1.7	1.1	1.8	4.6	7	130.9	11.5	78.6	0	6.0
17961	37	24	47	0	110	>500	8	10	11	<1	<1	<5	5	<1	30	1500	1600	2500	<500	1.2	1.7	2.2	5.1	7	138.5	11.9	78.5	0	6.7
20000	35	25	49	0	120	>500	10	17	14	<1	<1	<5	5	<1	45	1600	1800	2800	<500	1.9	1.6	2.6	6.1	7	nd	nd	nd	nd	5.9

TABLE 20. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 3F3072 VEHICLE TYPE 1-1/4 ton M715

CRANKCASE LUBRICANT CCL-O-147 ENGINE DESCRIPTION 6-230

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion V.I.	D I S P E R.	A N T I O X.	OXIDATION (%)	Metal Concentration (Expressed as parts per million by weight) Wear Metals Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants Si	B	Na	Lubricant Additives P	Zn	Ca	Ba	Physical Properties Micro-Filtration Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	Sludge Avg Agglomerate Size (μ)	Viscosity cS at 100°F	cS at 210°F	Vis. Index	Fuel Dilution (%) Vol	Makeup Oil (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	450	400	800	800	1.0	0.1	0.1	1.2	0	110.6	10.3	78	0	
59	0	0	0	0	15	300	3	1	2	<1	<1	<5	<1	<1	19	750	450	1000	1000	0.6	0.2	0.5	1.3	0	102.9	9.9	80.0	0	0
2000	3	16	40	0	120	>500	11	4	3	<1	<1	<5	3	<1	7	600	400	900	1100	1.2	1.3	1.3	3.8	5	117.3	10.7	77.0	0	5.4
4260	nc	nc	nc	3	140	>500	3	12	6	<1	<1	<5	3	<1	15	600	400	950	1000	0.9	0.6	0.6	2.1	7	123.2	11.1	78.5	0	5.7
5816	nc	nc	nc	5	200	>500	17	23	12	<1	<1	<5	7	<1	14	750	500	1000	2000	1.9	1.6	1.3	4.8	7	122.5	11.1	79.5	Tr	8.0
8000	0	37	0	0	96	>500	5	13	4	<1	<1	<5	1	<1	14	450	400	750	800	1.1	1.2	0.6	2.9	7	119.9	10.8	78.0	0	2.4
10003	nc	nc	nc	6	160	>500	11	29	9	<1	<1	<5	3	<1	14	600	400	900	1100	1.3	0.6	0.6	2.5	21	127.1	11.8	87.0	0	6.1
12034	nc	nc	nc	6	160	>500	14	34	10	<1	<1	<5	3	<1	4	450	400	800	800	0.8	0.8	1.6	3.2	>100	130.5	11.8	83.0	1.0	5.5
13800	15	29	45	0	37	>500	4	3	1	<1	<1	<5	1	<1	10	600	400	900	900	1.6	0.4	0.7	2.7	7	114.7	10.5	77.5	Tr	'1.4
16000	nc	nc	nc	3	96	>500	4	18	6	<1	<1	<5	2	<1	1	500	450	1000	1000	2.8	1.1	0.9	4.8	7	130.6	11.4	73.3	0	5.6
18091	nc	nc	nc	6	110	>500	5	17	9	<1	<1	<5	2	<1	11	650	450	1000	1800	2.5	1.5	1.2	5.2	7	132.9	12.0	84.5	0	6.5
20000	nc	nc	nc	8	85	>500	4	10	5	<1	<1	<5	1	<1	10	600	400	950	1100	3.3	1.5	0.8	5.6	7	157.5	12.7	75.0	0	3.9

TABLE 21. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 3F3175 VEHICLE TYPE 1-1/4 ton M715

CRANKCASE LUBRICANT CCL-O-144 ENGINE DESCRIPTION 6-230

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion: V.I.	I.R. Percent Additive Depletion: DISPER.	I.R. Percent Additive Depletion: ANTIOX.	I.R. OXIDATION (%)	Metal Concentration (expressed as parts per million by weight) Wear Metals: Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants: Si	B	Na	Lubricant Additives: P	Zn	Ca	Ba	Physical Properties Micro-Filtration: Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	Sludge: AVG AGGLOMERATE SIZE (μ)	Viscosity: CS AT 100°F	CS AT 210°F	VIS. INDEX	FUEL DILUTION (%) Vol	MAKEUP OIL (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	9	<1	<1	800	500	950	1000	0.1	0.2	0.2	0.5	0	104.6	11.2	101	0	–
50	0	0	0	0	39	300	4	1	2	<1	<1	<5	10	<1	40	800	500	900	1100	0.4	0.3	0.7	1.4	0	96.7	10.8	103.5	0	0
2029	nc	nc	nc	2	170	>500	10	4	11	<1	<1	<5	13	<1	30	800	450	950	1900	0.5	0.6	1.3	2.4	5	113.1	11.9	103.0	0	5.3
4006	nc	nc	nc	3	120	>500	9	6	10	<1	<1	<5	11	<1	25	700	400	1100	1800	0.3	1.1	1.1	2.5	6	117.6	12.1	100.5	0	3.8
5787	nc	nc	nc	7	120	>500	8	14	12	<1	<1	<5	12	<1	20	850	500	1100	2400	1.5	1.8	3.0	6.3	5	121.6	12.3	100.0	0	7.6
8271	nc	nc	nc	5	70	>500	1	13	6	<1	<1	<5	8	<1	10	600	500	1000	1300	1.1	1.7	2.6	5.4	7	116.7	12.1	101.5	0	5.4
10174	nc	nc	nc	6	76	>500	1	30	8	<1	<1	<5	9	<1	7	700	450	1100	2000	1.2	0.9	1.9	4.0	14	121.8	12.4	100.0	Tr	5.8
12060	nc	nc	nc	10	125	>500	5	60	18	<1	<1	<5	14	<1	1	800	600	1200	2100	1.2	1.0	2.3	4.5	7	121.4	12.2	98.5	0	3.6
13860	nc	nc	nc	3	50	>500	3	10	5	<1	<1	<5	7	<1	7	800	500	1100	2000	1.2	0.4	1.1	2.7	7	115.1	12.0	101.0	1.0	7.4
17009	nc	nc	nc	4	120	>500	5	39	18	<1	<1	<5	15	<1	5	750	600	1000	2100	1.4	1.0	1.8	4.2	7	121.0	12.3	99.5	–	7.3
18654	nc	nc	nc	7	90	>500	4	32	14	<1	<1	<5	12	<1	1	700	500	1100	1300	2.0	1.3	1.9	5.2	7	139.1	12.9	92.2	0	4.1
18935	nc	nc	nc	8	97	>500	4	36	16	<1	<1	<5	12	<1	1	700	500	1200	1300	2.6	1.3	1.8	5.7	7	143.8	13.5	96.1	0	0
200C	nc	nc	nc	10	92	>500	4	37	18	<1	<1	<5	11	<1	6	700	500	1000	2100	2.7	1.6	2.6	6.9	7	133.4	12.7	94.0	0	0

TABLE 22. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 4J4609 VEHICLE TYPE 2-1/2 ton M35A2

CRANKCASE LUBRICANT CCL-O-144 ENGINE DESCRIPTION LD-465-1

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion: V.I.	I.R. Percent Additive Depletion: DISPER.	I.R. Percent Additive Depletion: ANTIOX.	I.R. OXIDATION (%)	Wear Metals: Fe	Wear Metals: Pb	Wear Metals: Cu	Wear Metals: Cr	Wear Metals: Al	Wear Metals: Ni	Wear Metals: Ag	Wear Metals: Sn	Contaminants: Si	Contaminants: B	Contaminants: Na	Lubricant Additives: P	Lubricant Additives: Zn	Lubricant Additives: Ca	Lubricant Additives: Ba	Micro-Filtration: Wt % > 5μ	Micro-Filtration: Wt % 1.2 – 5μ	Micro-Filtration: Wt % 0.22 – 1.2μ	Micro-Filtration: Total Wt % > 0.22μ	Sludge: AVG AGGLOMERATE SIZE (μ)	Viscosity: CS AT 100°F	Viscosity: CS AT 210°F	Viscosity: VIS. INDEX	FUEL DILUTION (%) Vol	MAKEUP OIL (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	9	<1	<1	800	500	950	1000	0.1	0.2	0.2	0.5	na	104.6	11.2	101	0	–
52	0	0	0	0	16	7	5	1	<1	<1	<1	<5	8	<1	3	700	500	1000	800	0.2	0.2	0.8	1.2	na	99.9	10.9	102.5	nd	0
2012	nc	nc	nc	2	94	48	18	4	6	<1	<1	<5	9	<1	12	650	500	950	900	0.5	0.4	0.9	1.8	na	104.9	11.4	103.0	nd	6.7
4000	nc	nc	nc	4	160	50	23	4	11	<1	<1	<5	12	<1	8	800	550	1100	1100	0.4	0.5	0.2	1.1	na	110.0	11.7	103.0	nd	6.1
5845	nc	nc	nc	5	220	180	25	6	20	<1	<1	<5	14	<1	15	900	600	1100	1900	1.1	0.8	1.2	3.1	na	115.2	12.2	103.5	0.1	7.7
8004	0	10	0	0	64	12	5	<1	5	<1	<1	<5	6	<1	4	850	400	950	1100	0.8	0.4	1.0	2.2	na	108.8	11.6	102.5	nd	6.8
10012	nc	nc	nc	6	85	8	7	<1	7	<1	<1	<5	6	<1	1	800	450	900	900	1.0	0.3	0.9	2.2	na	113.7	12.2	105.0	nd	6.9
12012	nc	nc	nc	7	150	22	8	1	11	<1	<1	<5	6	<1	6	900	500	1200	1500	0.8	0.5	1.1	2.4	na	114.6	12.1	103.5	0.2	5.3
13825	30	18	33	0	110	24	3	2	24	<1	<1	<5	9	<1	1	900	400	850	1300	1.7	0.8	0.7	3.2	na	105.6	11.6	105.0	nd	8.0
16006	nc	nc	nc	4	160	37	8	4	26	<1	<1	<5	9	<1	1	650	400	1000	1000	1.4	0.9	1.2	3.5	na	112.0	12.8	113.0	nd	3.8
18179	nc	nc	nc	5	190	28	9	6	33	<1	<1	<5	6	<1	5	650	400	850	1000	1.5	0.8	1.6	3.9	na	108.5	11.8	105.0	nd	10.2
20000	nc	nc	nc	7	270	36	10	7	45	<1	<1	<5	13	<1	7	750	450	900	1200	1.4	2.3	1.4	5.1	na	120.3	13.9	117.0	1.2	0

TABLE 23. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 4J2578 VEHICLE TYPE 2-1/2 ton M35A2

CRANKCASE LUBRICANT CCL-O-146 ENGINE DESCRIPTION LD-465-1

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R.				METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT)																PHYSICAL PROPERTIES									MAKEUP OIL
	PERCENT ADDITIVE DEPLETION			OXIDATION	WEAR METALS								CONTAMINANTS			LUBRICANT ADDITIVES					MICRO-FILTRATION				SLUDGE	VISCOSITY			FUEL DILUTION	
	V.I.	DISPER.	ANTIOX.	(%)	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba	Wt % > 5µ	Wt % 1.2 – 5µ	Wt % 0.22 – 1.2µ	Total Wt % > 0.22µ	AVG AGGLOMERATE SIZE (µ)	CS AT 100°F	CS AT 210°F	VIS. INDEX	(%) Vol	(LB)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	<1	<1	10	1300	1300	2400	<500	0.4	0.3	0.7	1.4	na	120.1	12.0	97	0	-
66	0	0	0	0	13	<5	<1	<1	3	<1	<1	<5	2	<1	12	1400	1200	2400	<500	0.2	0.2	0.8	1.2	na	113.9	11.8	100.0	nd	0
1961	35	12	34	0	60	12	5	2	6	<1	<1	<5	4	<1	20	1100	1100	2100	<500	0.5	0.4	1.1	2.0	na	117.0	12.0	100.0	nd	6.0
4084	76	32	68	0	120	18	7	3	10	<1	<1	<5	5	<1	15	1200	1100	2300	<500	0.5	0.6	1.4	2.5	na	122.5	12.4	100.5	nd	11.2
5804	nc	nc	nc	4	240	32	11	5	16	<1	<1	<5	8	<1	30	1600	1200	2400	<500	0.6	0.6	2.4	3.6	na	127.9	12.9	101.0	0.3	8.9
8247	15	5	0	0	68	<5	3	<1	6	<1	<1	<5	2	<1	20	1400	1300	2400	<500	0.5	0.4	1.3	2.2	na	123.7	12.5	100.5	nd	4.9
9922	15	10	10	0	92	6	4	<1	8	<1	<1	<5	2	<1	8	1200	1200	2400	<500	0.7	0.7	1.6	3.0	na	121.0	12.4	101.5	nd	10.3
12016	nc	nc	nc	3	170	320	7	<1	9	<1	<1	<5	2	<1	7	1200	1300	2400	<500	0.6	0.6	1.9	3.1	na	131.0	13.1	101.5	nd	7.2
13834	37	21	37	0	70	22	2	<1	9	<1	<1	<5	2	<1	30	1400	1200	2200	<500	0.9	0.6	1.3	2.8	na	118.8	12.2	101.0	nd	3.6
16000	21	18	32	0	100	18	4	1	12	<1	<1	<5	3	<1	5	1300	1200	1900	<500	1.1	0.8	1.5	3.4	na	123.4	12.6	101.5	nd	8.1
18035	27	24	43	0	160	32	7	2	18	<1	<1	<5	6	<1	10	1200	1300	2500	<500	1.2	1.2	1.8	4.2	na	127.2	13.0	103.5	nd	7.4
20000	31	25	52	0	270	38	9	3	28	<1	<1	<5	7	<1	35	1500	1300	2400	<500	1.8	0.7	2.8	5.3	na	126.1	13.0	104.0	0	3.8

TABLE 24. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 4J2594 VEHICLE TYPE 2-1/2 ton M35A2

CRANKCASE LUBRICANT CCL-O-147 ENGINE DESCRIPTION LD-465-1

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion V.I.	I.R. Percent Additive Depletion DISPER.	I.R. Percent Additive Depletion ANTIOX.	I.R. OXIDATION (%)	Wear Metals Fe	Wear Metals Pb	Wear Metals Cu	Wear Metals Cr	Wear Metals Al	Wear Metals Ni	Wear Metals Ag	Wear Metals Sn	Contaminants Si	Contaminants B	Contaminants Na	Lubricant Additives P	Lubricant Additives Zn	Lubricant Additives Ca	Lubricant Additives Ba	Micro-Filtration Wt % > 5µ	Micro-Filtration Wt % 1.2 – 5µ	Micro-Filtration Wt % 0.22 – 1.2µ	Micro-Filtration Total Wt % > 0.22µ	Sludge AVG AGGLOMERATE SIZE (µ)	Viscosity CS AT 100°F	Viscosity CS AT 210°F	Viscosity VIS. INDEX	FUEL DILUTION (%) Vol	MAKEUP OIL (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	450	400	800	800	1.0	0.1	0.1	1.2	na	110.6	10.3	78	0	–
59	0	0	0	0	26	5	<1	2	2	<1	<1	<5	<1	<1	3	650	500	1100	1000	0.2	0.2	0.9	1.3	na	106.5	10.2	80.0	nd	0
2174	7	22	47	0	50	10	8	1	2	<1	<1	<5	<1	<1	10	500	400	750	800	0.3	0.8	0.4	1.5	na	109.4	10.3	79.5	nd	3.8
4009	nc	nc	nc	3	97	12	14	<1	2	<1	<1	<5	2	<1	5	600	350	850	1000	0.8	0.7	1.2	2.7	na	115.4	10.8	81.5	nd	6.8
5820	nc	nc	nc	5	210	18	19	4	11	<1	<1	<5	5	<1	12	800	400	800	1300	1.3	1.0	1.3	3.6	na	126.7	11.8	88.0	0.3	10.3
8102	0	37	0	0	33	5	7	<1	<1	<1	<1	<5	24	<1	5	600	300	800	700	0.4	0.4	0.7	1.5	na	114.8	10.5	77.0	nd	0
10001	nc	nc	nc	4	52	85	8	<1	2	<1	<1	<5	<1	<1	1	400	300	700	700	0.7	0.5	0.8	2.0	na	118.9	10.9	80.5	nd	7.7
12002	nc	nc	nc	4	105	6	8	<1	<1	<1	<1	<5	<1	<1	5	600	300	700	900	0.8	0.3	0.7	1.8	na	126.0	11.6	85.5	0.4	8.6
13806	11	17	52	0	40	7	3	<1	2	<1	<1	<5	<1	<1	6	500	300	650	750	1.1	0.5	0.8	2.4	na	110.5	10.6	84.5	nd	10.8
15998	nc	nc	nc	0	97	10	7	<1	8	<1	<1	<5	<1	<1	1	500	300	650	700	1.4	0.6	0.8	2.8	na	117.3	11.6	94.0	nd	13.3
18016	nc	nc	nc	6	200	22	9	1	18	<1	<1	<5	3	<1	1	500	350	800	800	1.2	1.2	1.8	4.2	na	132.3	13.8	108.0	nd	7.4
20000	nc	nc	nc	7	280	26	9	5	24	<1	<1	<5	5	<1	7	500	350	600	700	2.6	0.5	0.2	3.3	na	141.0	15.3	115.0	1.7	8.5

TABLE 25. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 4J2695 VEHICLE TYPE 2-1/2 ton M35A2

CRANKCASE LUBRICANT CCL-O-147 ENGINE DESCRIPTION LD-465-1

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	ANALYTICAL DATA																												
	I.R.				METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT)															PHYSICAL PROPERTIES									MAKEUP OIL
	PERCENT ADDITIVE DEPLETION			OXIDATION	WEAR METALS								CONTAMINANTS			LUBRICANT ADDITIVES				MICRO-FILTRATION				SLUDGE	VISCOSITY			FUEL DILUTION	
	V.I.	DISPER.	ANTIOX.	(%)	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba	Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	AVG AGGLOMERATE SIZE (μ)	CS AT 100°F	CS AT 210°F	VIS. INDEX	(%) Vol	(LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	450	400	800	800	1.0	0.1	0.1	1.2	na	110.6	10.3	78	0	-
54	0	0	0	0	4	5	1	<1	<1	<1	<1	<5	<1	<1	2	700	500	1100	900	0.2	0.3	0.5	1.0	na	105.7	10.2	80.5	nd	0
1901	20	23	40	0	21	8	5	<1	<1	<1	<1	<5	<1	<1	1	700	480	800	1800	0.3	0.3	0.5	1.1	na	107.2	10.2	80.5	nd	15.3
4000	31	42	60	0	22	8	9	<1	<1	<1	<1	<5	<1	<1	2	500	350	800	800	0.4	0.3	0.5	1.2	na	116.2	10.6	78.5	nd	9.0
5806	nc	nc	nc	5	78	20	13	<1	<1	<1	<1	<5	2	<1	10	800	400	850	1300	0.5	0.6	0.2	1.3	na	124.5	11.5	84.5	0.4	9.5
8025	0	26	0	0	11	6	3	<1	<1	<1	<1	<5	<1	<1	5	600	350	800	900	0.3	0.3	0.5	1.1	na	115.7	10.6	78.5	nd	10.6
10001	nc	nc	nc	4	20	14	5	<1	<1	<1	<1	<5	<1	<1	1	500	300	750	800	0.7	0.5	0.9	2.1	na	122.5	11.0	78.0	nd	10.3
11993	nc	nc	nc	6	20	6	5	1	1	<1	<1	<5	1	<1	1	800	400	700	800	1.1	0.6	0.7	2.4	na	110.2	10.3	78.0	0.5	7.3
16034	nc	nc	nc	3	120	20	8	2	12	<1	<1	<5	4	<1	4	600	400	700	900	2.2	0.6	0.5	3.3	na	nd	nd	nd	nd	18.8
17976	nc	nc	nc	8	210	65	11	4	18	<1	<1	<5	6	<1	1	600	400	750	800	2.9	1.1	0.3	4.3	na	nd	nd	nd	nd	12.2
20000	nc	nc	nc	12	290	32	13	5	22	<1	<1	<5	6	<1	10	700	400	600	1000	3.8	0.5	0.6	4.9	na	174.9	16.4	105.5	0.8	12.4

TABLE 26. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 4J4623 VEHICLE TYPE 2-1/2 ton M35A2

CRANKCASE LUBRICANT CCL-O-145 ENGINE DESCRIPTION LD 465-1

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion V.I.	I.R. Percent Additive Depletion DISPER.	I.R. Percent Additive Depletion ANTIOX.	I.R. OXIDATION (%)	Metal Concentration (Expressed as parts per million by weight) Wear Metals Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants Si	B	Na	Lubricant Additives P	Zn	Ca	Ba	Physical Properties Micro-Filtration Wt % > 5µ	Wt % 1.2 - 5µ	Wt % 0.22	Total Wt % > 0.22µ	Sludge Avg Agglomerate Size (µ)	Viscosity cS at 100°F	cS at 210°F	Vis. Index	Fuel Dilution (%) Vol	Makeup Oil (LB)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	3	<1	8	1400	1500	2100	<500	0.7	0.2	0.6	1.5	na	129.5	12.6	96	0	–
61	0	0	0	0	7	5	1	<1	<1	<1	<1	<5	3	<1	14	1500	1500	2100	<500	0.2	0.3	1.0	1.5	na	110.3	10.8	88.5	nd	0
2036	44	10	22	0	48	18	12	<1	1	5	<1	<5	5	<1	20	1300	1400	2200	<500	0.6	0.7	1.0	2.3	na	111.6	10.3	76.0	nd	9.7
4060	54	40	41	0	92	25	16	<1	9	<1	<1	<5	9	<1	18	1600	1400	2600	<500	0.9	1.0	2.2	4.1	na	119.4	10.9	79.5	nd	7.6
5805	nc	nc	nc	12	130	35	19	<1	16	<1	<1	<5	10	<1	25	1700	1600	2500	<500	0.9	0.4	0.9	2.2	na	129.3	11.4	79.0	0	13.9
7956	21	10	20	0	50	<5	4	<1	6	<1	<1	<5	5	<1	12	1600	1600	2400	<500	0.6	0.5	1.4	2.5	na	118.6	11.1	83.0	nd	5.7
10012	20	18	30	0	69	7	6	1	10	<1	<1	<5	4	<1	7	1500	1600	2700	<500	1.0	0.3	0.9	2.2	na	131.2	11.5	77.0	nd	7.6
12000	28	22	55	0	118	18	9	2	15	<1	<1	<5	4	<1	20	1600	1600	2400	<500	1.6	1.1	1.6	4.3	na	142.2	12.2	79.0	0	7.6
13803	17	22	30	0	60	28	4	2	22	<1	<1	<5	3	<1	11	1700	1600	2200	<500	1.5	0.5	1.0	3.0	na	116.4	10.7	79.0	nd	10.3
15960	27	10	32	0	82	12	7	3	21	<1	<1	<5	5	<1	3	1500	1400	2100	<500	2.8	1.0	1.1	4.9	na	129.1	11.9	87.0	nd	7.9
17976	28	29	46	0	130	24	9	4	28	<1	<1	<5	7	<1	15	1400	1400	2400	<500	2.8	1.1	1.2	5.1	na	139.5	12.2	82.5	nd	3.9
20000	nc	nc	nc	6	170	24	10	3	36	<1	<1	<5	7	<1	20	1500	1400	2400	<500	3.1	2.4	1.9	7.4	na	160.6	14.0	91.0	0	11.6

TABLE 27. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 5E5775 VEHICLE TYPE 5 ton M54A2

CRANKCASE LUBRICANT CCL-O-146 ENGINE DESCRIPTION LDS-465-1A

na = not applicable nc = not calculatable nd = not determined Tr = trace

MILEAGE	ANALYTICAL DATA: I.R. — PERCENT ADDITIVE DEPLETION				METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT)																PHYSICAL PROPERTIES									
					WEAR METALS								CONTAMINANTS			LUBRICANT ADDITIVES				MICRO-FILTRATION				SLUDGE	VISCOSITY			FUEL DILUTION	MAKEUP OIL
	V.I.	DISPER.	ANTIOX.	OXIDATION (%)	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba	Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	AVG AGGLOMERATE SIZE (μ)	CS AT 100°F	CS AT 210°F	VIS. INDEX	(%) Vol	(LBS)
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	<1	<1	10	1300	1300	2400	<500	0.4	0.3	0.7	1.4	na	120.1	12.0	97	0	0
93	0	0	0	0	10	5	1	<1	3	4	<1	<5	2	<1	13	1400	1200	2100	<500	0.4	0.5	1.1	2.0	na	113.1	11.7	99.5	nd	0
1998	nc	nc	nc	5	96	18	7	6	5	<1	<1	<5	5	<1	30	[illegible]	1000	2100	<500	0.6	0.5	1.2	2.3	na	122.0	12.1	97.0	nd	6.9
3910	nc	nc	nc	43	240	180	21	8	30	<1	<1	<5	12	<1	20	1300	1100	2400	<500	1.9	0.5	1.0	3.4	na	223.7	17.6	92.0	nd	15.4
5798	nc	nc	nc	70	405	490	68	8	22	<1	<1	<5	15	<1	32	1500	1100	2400	<500	5.5	0.9	1.5	7.9	na	387.3	31.1	131.0	[illegible]	22.1
6952	nc	nc	nc	19	140	105	58	2	6	<1	<1	<5	5	<1	15	1300	1200	2200	<500	0.9	0.9	2.1	3.9	na	142.6	13.7	99.0	nd	14.9
8888	nd	nd	nd	nd	160	30	18	6	12	<1	<1	<5	13	<1	20	1300	1100	2600	<500	nd	nd	nd	nd	na	nd	nd	nd	nd	36.7
9984	nc	nc	nc	19	190	36	17	7	14	<1	<1	<5	12	<1	18	1300	1100	2600	<500	1.5	0.6	2.0	4.1	na	147.5	14.0	99.5	nd	13.9
12010	nc	nc	nc	60	520	210	23	17	25	<1	<1	<5	20	<1	15	1500	1300	2800	<500	5.4	0.8	1.2	7.4	na	327.5	36.3	128.0	0	40.3
13034	nd	nd	nd	nd	320	24	14	10	28	<1	<1	<5	13	37	140	1200	1100	2200	<500	3.6	0.6	1.3	5.5	na	200.8	27.3	135.0	nd	22.8
13947	nc	nc	nc	3	23	310	46	2	<1	<1	<1	<5	<1	11	40	1000	1200	1600	<500	1.6	0.4	0.9	2.9	na	118.5	11.4	90.0	nd	55.0
14095	nc	nc	nc	4	10	96	62	<1	<1	<1	<1	<5	10	4	80	800	700	1100	<500	0.8	0.3	0.7	1.8	na	113.8	11.5	97.0	0.2	na

TABLE 28. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 5E5774 VEHICLE TYPE 5 ton M54A2

CRANKCASE LUBRICANT CCL-O-147 ENGINE DESCRIPTION LDS-465-1A

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. PERCENT ADDITIVE DEPLETION V.I.	DISPER.	ANTIOX.	OXIDATION (%)	METAL CONCENTRATION (EXPRESSED AS PARTS PER MILLION BY WEIGHT) WEAR METALS Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	CONTAMINANTS Si	B	Na	LUBRICANT ADDITIVES P	Zn	Ca	Ba	PHYSICAL PROPERTIES MICRO-FILTRATION Wt % > 5μ	Wt % 1.2 – 5μ	Wt % 0.22 – 1.2μ	Total Wt % > 0.22μ	SLUDGE AVG AGGLOMERATE SIZE (μ)	VISCOSITY CS AT 100°F	CS AT 210°F	VIS. INDEX	FUEL DILUTION (%) Vol	MAKEUP OIL (LB)
0	0	0	0	0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	450	400	800	800	1.0	0.1	0.1	1.2	na	110.6	10.3	78	0	–
99	0	0	0	0	7	<5	2	<1	<1	<1	<1	<5	<1	<1	8	800	500	900	1100	0.4	0.4	1.5	2.4	na	102.3	9.9	80.5	nd	0
2054	10	19	45	0	21	<5	2	11	<1	<1	<1	<5	<1	<1	8	500	350	750	700	0.4	0.3	0.6	1.3	na	115.7	10.6	77.5	nd	9.1
4007	nc	nc	nc	12	78	<5	9	2	<1	<1	<1	<5	<1	<1	20	500	250	700	600	1.1	0.5	0.8	2.3	na	133.5	11.9	82.5	nd	6.0
5805	nc	nc	nc	40	170	14	10	5	3	<1	<1	<5	2	<1	25	650	350	550	800	0.8	0.1	0.4	1.3	na	145.7	12.5	81.0	0.3	12.3
8090	nc	nc	nc	10	95	<5	6	<1	1	<1	<1	<5	<1	<1	<1	300	250	600	500	0.9	0.3	0.6	1.8	na	124.4	11.2	80.5	nd	22.7
10064	nc	nc	nc	15	200	8	7	4	55	<1	<1	<5	15	<1	<1	400	200	450	<500	1.8	0.3	0.7	2.8	na	144.4	12.4	81.0	nd	16.4
12674	nc	nc	nc	18	320	120	20	7	15	<1	<1	<5	5	<1	11	600	300	550	700	4.7	0.3	0.5	5.5	na	252.7	21.8	109.0	nd	22.1
14000	nc	nc	nc	15	70	20	6	<1	3	<1	<1	<5	8	<1	<1	450	350	600	800	2.0	0.3	0.6	2.9	na	128.5	11.8	86.0	nd	7.0
16001	nc	nc	nc	19	62	12	6	<1	<1	<1	<1	<5	<1	<1	4	400	200	300	<500	1.4	0.3	0.5	2.2	na	143.8	11.9	72.0	nd	27.5
17451	nc	nc	nc	20	170	34	9	<1	<1	<1	<1	<5	<1	<1	5	500	300	350	<500	2.2	0.4	0.7	3.3	na	157.4	13.9	91.0	1.1	7.0

TABLE 29. SUMMARY OF OIL ANALYSIS DATA

Analytical evaluations performed by U.S. Army Fuels and Lubricants Research Laboratory (Appendix II, procedures) except for metal concentrations obtained by Analysts, Inc., Oakland, California

VEHICLE NO. 5E5776 VEHICLE TYPE 5 ton M54A2

CRANKCASE LUBRICANT CCL-O-145 ENGINE DESCRIPTION LDS-465-1A

na = not applicable nc = not calculatable nd = not determined Tr = trace

ANALYTICAL DATA

MILEAGE	I.R. Percent Additive Depletion: V.I.	Disper.	Antiox.	Oxidation (%)	Metal Concentration (Expressed as parts per million by weight) — Wear Metals: Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Contaminants: Si	B	Na	Lubricant Additives: P	Zn	Ca	Ba	Physical Properties — Micro-Filtration: Wt % > 5µ	Wt % 1.2 – 5µ	Wt % 0.22 – 1.2µ	Total Wt % > 0.22µ	Sludge: Avg Agglomerate Size (µ)	Viscosity: cS at 100°F	cS at 210°F	Vis. Index	Fuel Dilution (%) Vol	Makeup Oil ([illegible])
0	0	0	0	0	<1	<5	<1	<1	3	<1	<1	<5	3	<1	8	1400	1500	2100	<500	0.7	0.2	0.6	1.5	na	129.5	12.6	96	0	—
90	0	0	0	0	14	<5	2	<1	4	<1	<1	<5	5	<1	16	1600	1400	2000	<500	0.2	0.1	0.6	0.9	na	107.8	10.6	87.5	nd	0
1967	50	3	32	0	95	8	7	3	5	<1	<1	<5	6	<1	25	1400	1400	2100	<500	0.6	0.6	1.5	2.2	na	114.3	10.4	75.0	nd	[illegible].5
4013	nc	nc	nc	33	160	18	10	7	10	<1	<1	<5	8	<1	20	1600	1400	2400	<500	2.2	0.4	0.8	3.4	na	137.1	11.7	76.0	nd	1[illegible].3
5793	nc	nc	nc	12	220	34	15	10	14	<1	<1	<5	12	<1	35	1700	1600	2400	<500	2.4	1.4	0.6	4.4	na	164.5	12.8	71.0	0.1	7.9
7930	nc	nc	nc	15	105	10	7	5	9	<1	<1	<5	8	<1	8	16[illegible]0	1600	2800	<500	2.3	0.6	0.7	3.6	na	132.2	11.6	75.0	nd	9.8
9912	nc	nc	nc	15	130	18	7	5	9	<1	<1	<5	7	<1	18	1600	1600	2200	<500	3.9	0.9	0.8	5.3	na	nd	nd	nd	nd	14.8
11890	nc	nc	nc	18	200	10	10	8	21	<1	<1	<5	12	<1	10	1700	1300	2400	<500	5.0	0.3	0.7	6.0	na	226.3	18.1	95.5	0.1	7.8
14034	nc	nc	nc	9	170	24	8	7	23	<1	<1	<5	10	<1	15	1300	1300	2100	<500	3.5	1.2	1.3	6.0	na	134.6	14.6	113.0	nd	0.0
15288	nd	nd	nd	nd	250	30	12	9	32	<1	<1	<5	12	<1	22	1500	1300	2200	<500	4.2	2.8	1.5	8.5	na	150.9	17.2	122.0	nd	4.1
16199	nc	nc	nc	22	270	32	12	10	36	<1	<1	<5	16	<1	30	1400	1300	2100	<500	2.8	2.8	1.2	6.8	na	nd	nd	nd	nd	4.9
18220	nc	nc	nc	28	390	37	18	14	47	<1	<1	<5	17	<1	35	1400	1400	2100	<500	4.6	0.8	0.6	6.0	na	183.5	19.1	118.0	nd	6.2
19119	nc	nc	nc	31	430	47	21	20	58	<1	<1	15	20	<1	20	1300	1400	1900	<500	nd	nd	nd	nd	na	nd	nd	nd	nd	5.8
20152	nc	nc	nc	40	500	46	29	19	47	2	<1	14	19	<1	25	1300	1400	1900	<500	5.3	1.4	1.0	7.7	na	219.8	28.7	133.0	0	5.9

TABLE 33

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 3B3632 **Lubricant No: CCL-G-148**

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	<1	<1	<1	<1	<1	<5	<1	<1	5	4600	5500	<50	<500
67	87	<5	<4	<1	<1	<1	<1	<5	<1	<1	5	4500	6100	<50	<500
4,057	130	18	13	<1	<1	<1	<1	<5	2	<1	15	4600	5200	<50	<500
8,118	170	10	23	<1	3	<1	<1	<5	8	<1	18	4400	5300	<50	<500
12,000	160	12	25	<1	3	<1	<1	<5	7	<1	10	4500	5500	<50	<500
16,017	190	120	29	<1	3	<1	<1	<5	12	<1	5	4400	5800	<50	<500
20,000	105	<5	25	<1	<1	<1	<1	<5	2	<1	<1	4400	5800	<50	<500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	<1	<1	<1	<1	<1	<5	<1	<1	5	4600	5500	<50	<500
67	80	<5	1	1	<1	<1	<1	<5	3	<1	25	4400	6100	<50	<500
4,057	190	<5	2	3	1	1	<1	<5	95	<1	35	3400	3400	<50	<500
8,118	580	<5	<1	1	<1	<1	<1	<5	8	<1	13	1700	1600	<50	<500
12,000	1900	<5	<1	1	<1	6	<1	<5	25	<1	9	2000	1800	<50	<500
16,017	2400	50	130	4	5	15	<1	<5	85	<1	40	4400	4900	<50	<500
20,000	1600	<5	2	<1	1	7	<1	<5	26	<1	<1	3200	3000	<50	<500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	<1	<1	<1	<1	<1	<5	<1	<1	5	4600	5500	<50	<500
67	410	38	24	1	<1	<1	<1	<5	9	<1	60	4700	6200	<50	<500
4,057	3200	52	190	3	2	14	<1	<5	34	<1	150	4500	3800	<50	<500
8,118	3900	48	380	10	6	33	<1	30	140	<1	150	4100	3000	<50	<500
12,000	840	25	380	2	1	10	<1	<5	39	<1	60	4600	5000	<50	<500
16,017	1200	10	400	2	<1	10	<1	<5	33	<1	45	3800	3000	<50	<500
20,000	1100	10	82	<1	<1	14	<1	<5	21	<1	6	4700	6300	<50	<500

TABLE 34

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 3G6207 Lubricant No: CCL-G-150

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1300	< 50	< 50	< 500
49	17	< 5	< 9	< 1	< 1	< 1	< 1	< 5	< 1	< 1	5	1200	< 50	< 50	< 500
3,900	74	< 6	19	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1300	< 50	< 50	< 500
8,080	82	< 5	20	< 1	< 1	< 1	< 1	< 5	2	< 1	1	1300	< 50	< 50	< 500
12,001	94	85	19	< 1	< 1	< 1	< 1	< 5	4	< 1	15	1300	< 50	< 50	< 500
16,081	95	< 5	18	< 1	< 1	< 1	< 1	< 5	11	< 1	5	1300	< 50	< 50	< 500
20,000	130	< 5	24	< 1	< 1	< 1	< 1	< 5	5	< 1	10	1500	< 50	< 50	< 500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	<10	1300	<50	<50	<500
49	59	<5	3	<1	<1	<1	<1	<5	3	<1	15	1200	<50	<50	<500
3,900	89	<5	<1	<1	<1	<1	<1	<5	6	<1	10	1200	<50	<50	<500
8,080	58	<5	<1	<1	1	<1	<1	<5	1	<1	<1	900	<50	<50	<500
12,001	39	<5	<1	<1	<1	<1	<1	<5	1	<1	8	550	<50	<50	<500
16,081	70	<5	<1	<1	<1	<1	<1	<5	1	<1	<1	500	<50	<50	<500
20,000	67	<5	<1	<1	<1	<1	<1	<5	1	<1	<1	700	<50	<50	<500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	<50	<50	<500
49	110	<5	39	<1	<1	<1	<1	<5	2	<1	40	1400	<50	<50	<500
93	79	<5	5	<1	<1	<1	<1	<5	1	<1	20	1300	<50	<50	<500
3,900	300	<5	60	2	<1	<1	<1	<5	30	<1	65	1300	<50	<50	<500
8,080	240	7	50	<1	<1	<1	<1	<5	22	<1	18	1300	<50	<50	<500
12,001	490	6	64	1	2	<1	<1	<5	40	<1	50	1400	<50	<50	<500
16,081	200	<5	32	<1	<1	<1	<1	<5	7	<1	5	1100	<50	<50	<500

TABLE 35

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 3F3183 **Lubricant No: CCL-G-151**

Transmission

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
	Metal														
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
50	<1	<5	4	<1	1	<1	<1	<5	1	<1	25	1600	<50	<50	<500
4,000	270	<5	7	<1	8	<1	<1	<5	10	<1	35	1500	<50	<50	<500
8,290	160	220	72	<1	100	<1	<1	<5	220	<1	25	1600	<50	<50	<500
12,177	160	5	64	<1	110	<1	<1	<5	320	<1	5	1600	<50	<50	<500
16,000	210	100	62	<1	115	<1	1	<5	220	<1	8	1700	<50	<50	<500
20,000	180	105	46	<1	96	<1	<1	<5	160	<1	20	1700	<50	<50	<500

Transfer Gear

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
	Metal														
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
50	25	<5	<1	<1	1	<1	<1	<5	3	<1	45	1600	<50	<50	<500
4,000	42	8	50	<1	64	<1	<1	<5	110	<1	20	1700	<50	<50	<500
8,290	380	<5	<1	<1	<1	<1	<1	<5	1	<1	45	1300	<50	<50	<500
12,177	330	<5	<1	<1	<1	<1	<1	<5	1	<1	10	1200	<50	<50	<500
16,000	380	<5	<1	<1	<1	<1	<1	<5	1	<1	10	950	<50	<50	<500
20,000	290	<6	<1	<1	<1	<1	<1	<5	2	<1	30	1400	<50	<50	<500

Rear Axle

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
	Metal														
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
50	57	<5	<1	<1	<1	<1	<1	<5	5	<1	18	1500	<50	<50	<500
4,000	800	<5	<1	<1	<1	<1	<1	<5	5	<1	25	1800	<50	<50	<500
8,290	690	<5	<1	<1	<1	<1	<1	<5	13	<1	25	1600	<50	<50	<500
12,177	760	<5	1	<1	<1	1	<1	<5	44	<1	2	1700	<50	<50	<500
16,000	3200	<5	<1	<1	<1	<1	<1	<5	7	<1	8	1400	<50	<50	<500
20,000	470	<6	2	<1	<1	<1	<1	<5	2	<1	20	1400	<50	<50	<500

TABLE 36

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 3F3078 **Lubricant No: CCL-G-150**

Transmission

	Metal														
Mileage	*Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	<50	<50	<500
51	<1	<5	1	<1	<1	<1	<1	<5	3	<1	10	1300	<50	<50	<500
4,009	26	<5	14	<1	37	<1	<1	<5	75	<1	8	1400	<50	<50	<500
8,195	76	<5	21	<1	60	<1	<1	<5	150	<1	20	1400	<50	<50	<500
16,010	120	<5	18	<1	65	<1	<1	<5	140	<1	5	1300	<50	<50	<500
20,000	42	20	11	<1	7	<1	<1	<5	12	<1	9	1400	<50	<50	<500

Transfer Gear

	Metal														
Mileage	*Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Nz*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	<50	<50	<500
51	11	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1400	<50	<50	<500
4,009	29	<5	<1	<1	<1	<1	<1	<5	20	<1	5	1200	<50	<50	<500
8,195	30	<5	<1	<1	<1	<1	<1	<6	<1	<1	10	950	<50	<50	<500
11,935	37	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	800	<50	<50	<500
16,010	150	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	700	<50	<50	<500
20,000	150	<5	<1	<1	<1	<1	<1	<5	1	<1	<1	700	<50	<50	<500

Rear Axle

	Metal														
Mileage	*Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	<50	<50	<500
51	25	<5	<1	<1	<1	<1	<1	<5	<1	<1	13	1400	<50	<50	<500
4,009	160	<5	3	<1	<1	<1	<1	<5	22	<1	13	1400	<50	400	<500
8,195	800	<5	3	2	<1	<1	<1	<5	100	7	25	1400	<50	700	<500
11,935	1200	35	4	4	5	5	<1	<5	130	7	20	1500	<50	750	<500
16,010	1960	<5	4	3	4	4	<1	<5	120	9	30	1400	<50	800	<500
20,000	2400	5	2	<1	2	3	<1	<5	80	20	30	1500	<50	600	<500

TABLE 37

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 3F3199 **Lubricant No: CCL-G-151**

Transmission

Mileage	Metal													
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
63	3	<5	6	<1	3	<1	<1	<5	6	<1	15	1400	<50	<50	<500
4,000	36	<5	38	<1	67	<1	<1	<5	110	<1	25	1600	<50	<50	<500
7,989	120	<5	52	<1	140	<1	<1	<5	290	<1	20	1500	<50	<50	<500
12,143	140	6	58	<1	160	<1	<1	<5	320	<1	4	1600	<50	<50	<500
16,042	220	5	50	<1	180	<1	<1	<5	360	<1	10	1700	<50	<50	<500
20,000	190	10	45	<1	160	<1	<1	<5	400	<1	20	1700	<50	<50	<500

Transfer Gear

Mileage	Metal													
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
63	13	<1	<1	<1	<1	<1	<1	<5	<1	<1	35	1500	<50	<50	<500
4,000	380	<5	<1	<1	<1	<1	<1	<5	<1	<1	50	1600	<50	<50	<500
7,989	180	<5	2	<1	<1	<1	<1	<5	1	<1	25	800	<50	<50	<500
12,143	57	110	<1	<1	<1	<1	<1	<5	2	<1	<1	350	<50	<50	<500
16,042	6	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	150	<50	<50	<500
20,000	160	<5	<1	<1	<1	<1	<1	<5	<1	<1	<1	1000	<50	<50	<500

Rear Axle

Mileage	Metal													
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
63	42	<5	<1	<1	<1	<1	<1	<5	<1	<1	15	1400	<50	<50	<500
4,000	430	<5	<1	<1	<1	<1	<1	<5	3	<1	40	1700	<50	<50	<500
7,989	320	<5	<1	<1	<1	<1	<1	<5	5	<1	25	1400	<50	<50	<500
12,143	640	<5	3	<1	<1	<1	<1	<5	11	<1	20	1600	<50	<50	<500
16,042	475	<5	1	<1	<1	<1	<1	<5	17	<1	20	1700	<50	<200	<500
20,000	390	20	<1	<1	<1	<1	<1	<5	16	<1	45	1700	<50	<50	<500

TABLE 38

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 3F3072 Lubricant No: CCL-G-148

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	5	4600	5500	< 50	< 500
59	90	< 5	6	< 1	< 1	< 1	< 1	< 5	< 1	< 1	25	4600	6200	< 50	< 500
4,260	180	< 5	24	< 1	< 1	< 1	< 1	< 5	50	< 1	20	4700	6500	< 50	< 500
8,000	190	< 5	29	< 1	< 1	< 1	< 1	< 5	3	< 1	15	4400	5800	< 50	< 500
12,034	170	7	29	< 1	< 1	< 1	< 1	< 5	6	< 1	< 1	4400	5900	< 50	< 500
16,000	270	< 5	37	< 1	< 1	< 1	< 1	< 5	24	< 1	< 1	2500	5700	< 50	< 500
20,000	49	5	40	< 1	< 1	< 1	< 1	< 5	30	< 1	10	4600	5900	< 50	< 500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	<1	<1	<1	<1	<1	< 5	<1	<1	5	4600	5500	< 50	<500
59	92	<5	<1	<1	<1	<1	<1	< 5	<1	<1	17	4000	5000	< 50	<500
4,260	200	<5	24	<1	1	<1	<1	< 5	58	<1	30	4800	6500	< 50	<500
8,000	150	<5	<1	<1	3	<1	<1	< 5	15	<1	15	900	400	< 50	<500
12,034	170	<5	<1	<1	<1	<1	<1	< 5	1	<1	<1	800	400	< 50	<500
16,000	270	<5	<1	<1	<1	<1	<1	< 5	1	<1	<1	600	350	< 50	<500
20,000	3600	12	8	3	<1	5	<1	< 5	14	<1	5	2000	400	< 50	<500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	<1	<1	<1	<1	<1	< 5	<1	<1	5	4600	5500	< 50	<500
59	110	7	<1	<1	<1	<1	<1	< 5	1	<1	<1	4500	5200	< 50	<500
4,260	490	18	2	<1	<1	1	<1	< 5	17	<1	30	4600	5500	< 50	<500
8,000	780	22	2	<1	<1	<1	<1	< 5	30	<1	18	4100	4200	200	<500
12,034	1080	24	3	<1	<1	5	<1	< 5	33	<1	11	4100	4200	250	<500
16,000	1240	70	3	<1	<1	6	<1	< 5	44	<1	7	4300	4100	200	<500
20,000	1000	18	2	<1	<1	2	<1	< 5	25	<1	13	4400	4300	150	<500

TABLE 39

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 3F3175 **Lubricant No: CCL-G-149**

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	8	1700	<50	<50	<500
50	110	<5	7	<1	15	<1	<1	<5	26	<1	30	1900	<50	<50	<500
4,006	620	35	28	<1	95	<1	<1	<5	190	<1	25	2100	<50	<50	<500
8,271	700	5	37	<1	100	<1	<1	<5	230	<1	20	1800	<50	<50	<500
12,060	850	<5	37	<1	110	<1	<1	<5	240	<1	7	1800	<50	<50	<500
17,009	1120	7	39	2	130	<1	<1	<5	320	<1	25	2000	<50	<50	<500
20,000	1300	70	44	<1	140	<1	<1	<5	350	<1	30	2400	<50	<50	<500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	8	1700	<50	<50	<500
50	110	<5	<1	<1	3	<1	<1	<5	7	<1	30	1700	<50	<50	<500
4,006	860	<5	<1	<1	1	2	<1	<5	2	<1	35	1900	<50	<50	<500
8,271	720	<5	<1	<1	<1	1	<1	<5	3	<1	35	1800	100	<50	<500
12,060	780	<5	<1	<1	<1	<1	<1	<5	2	<1	12	1700	200	<50	<500
17,009	1200	<5	<1	<1	<1	3	<1	<5	3	<1	25	1400	100	<50	<500
20,000	750	<5	<1	<1	<1	<1	<1	<5	1	<1	35	1800	<50	<50	<500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	8	1700	<50	<50	<500
50	170	<5	<1	<1	<1	<1	<1	<5	<1	<1	[illegible]	1700	<50	<50	<500
4,006	680	<5	<1	<1	<1	<1	<1	<5	5	<1	35	2000	<50	<50	<500
8,271	1350	<7	<1	2	2	6	<1	<5	92	<1	23	1900	<50	<50	<500
12,060	1440	<5	<1	1	1	3	<1	<5	82	<1	8	1900	<50	<50	<500
17,009	1609	6	<1	3	2	4	<1	5	60	3	35	1900	<50	<50	<500
20,000	2600	7	<1	3	2	3	<1	5	85	3	50	2200	<50	<50	<500

TABLE 40

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 4J4609 **Lubricant No. CCL-G-150**

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	< 50	< 50	< 500
52	22	<5	3	<1	<1	<1	<1	<5	<1	<1	7	1200	< 50	< 50	< 500
4,000	210	<5	6	3	<1	<1	<1	<5	4	<1	8	1400	< 50	< 50	< 500
8,004	310	<5	7	4	<1	<1	<1	<5	10	<1	13	1400	< 50	< 50	< 500
12,012	330	<5	7	3	<1	<1	<1	<5	3	<1	10	1500	< 50	< 50	< 500
16,006	330	<5	5	3	<1	<1	<1	<5	7	<1	5	1200	< 50	< 50	< 500
20,000	140	<5	1	<1	<1	<1	<1	<5	14	<1	12	1400	< 50	< 50	< 500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	< 50	< 50	< 500
52	11	<5	8	1	<1	<1	<1	<5	3	<1	10	1300	< 50	< 50	< 500
4,000	60	<5	13	15	<1	<1	<1	<5	10	<1	11	1300	< 50	< 50	< 500
8,004	92	<5	24	14	<1	<1	<1	<5	4	<1	10	1200	< 50	< 50	< 500
12,012	110	<5	35	17	<1	<1	<1	<5	3	<1	15	1300	< 50	< 50	< 500
16,006	210	<5	33	15	<1	<1	<1	<5	3	<1	5	1100	< 50	< 50	< 500
20,000	180	<5	25	8	<1	<1	<1	<5	39	<1	15	1400	< 50	< 50	< 500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	< 50	< 50	< 500
52	15	<5	<1	<1	2	<1	<1	<5	5	<1	16	1300	< 50	< 50	< 500
4,000	120	<5	<1	2	3	<1	<1	<5	10	<1	20	1400	< 50	< 50	< 500
8,004	140	12	2	<1	3	<1	<1	<5	22	<1	17	1300	< 50	< 50	< 500
12,012	340	<5	2	<1	8	<1	<1	<5	25	<1	35	1500	< 50	< 50	< 500
16,006	410	<5	[illegible]	1	9	<1	<1	<5	41	<1	25	1300	< 50	300	< 500
20,000	500	20	1	6	13	<1	<1	<5	95	<1	45	1600	< 50	200	< 500

TABLE 41

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 4J2578 **Lubricant No: CCL-G-149**

Transmission

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	8	1700	<50	<50	<500
66	80	<5	10	<1	<1	<1	<1	<5	2	<1	10	1500	<50	<50	<500
4,084	560	<5	23	30	2	<1	<1	<5	40	<1	16	1900	<50	<50	<500
8,247	850	6	29	30	2	<1	<1	<5	11	<1	15	1900	<50	<50	<500
12,016	1200	6	29	30	3	1	<1	<5	11	<1	5	1800	<50	<50	<500
16,000	1560	<5	80	16	<1	2	<1	<5	23	<1	13	1300	<50	<50	<500
20,000	1190	14	32	34	<1	2	<1	<5	35	<1	25	2100	<50	<50	<500

Transfer G.

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	8	1700	<50	<50	<500
66	42	<5	9	3	<1	<1	<1	<5	2	<1	20	1600	<50	<50	<500
4,084	580	6	39	34	1	2	<1	<5	75	<1	70	2000	200	<50	<500
8,247	980	5	58	32	2	5	<1	<5	30	<1	75	1700	200	<50	<500
12,016	1060	<5	68	22	1	3	<1	<5	26	<1	22	1500	200	<50	<500
16,000	1260	6	29	30	2	<1	<1	<5	14	<1	5	2100	100	<50	<500
20,000	900	<5	88	7	<1	<1	<1	<5	12	<1	25	1500	<50	<50	<500

Rear Axle

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	8	1700	<50	<50	<500
66	42	<5	<1	2	4	<1	<1	<5	12	<1	35	1600	<50	<50	<500
4,084	420	8	1	6	55	<1	<1	<5	200	<1	150	2000	<50	<50	<500
8,247	800	19	3	7	72	4	<1	<5	210	<1	150	2200	<50	<50	<500
016	1360	18	3	6	74	4	<1	<5	200	<1	80	2100	<50	<50	<500
,000	1080	14	3	6	65	5	<1	<5	180	<1	85	2200	<50	400	<500
20,000	1100	18	2	5	60	3	<1	<5	150	<1	150	1900	<50	400	<500

TABLE 42

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 4J2594 Lubricant No: CCL-G-148

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	<1	<1	<1	<1	<1	<5	<1	<1	5	4600	5500	<50	<500
59	320	<5	8	1	<1	2	<1	<5	1	<1	2	4500	5500	60	<500
4,009	780	6	21	2	<1	2	<1	<5	11	<1	7	4600	5900	<50	<500
8,102	760	10	26	2	<1	2	<1	<5	12	<1	8	4500	5800	<50	<500
12,002	790	11	26	3	<1	3	<1	<5	8	<1	10	4600	5500	<50	<500
15,998	960	<5	26	1	<1	2	<1	<5	15	<1	<1	4500	4900	<50	<500
20,000	1000	8	29	<1	<1	1	<1	<5	6	<1	9	4400	4600	<50	<500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	<1	<1	<1	<1	<1	<5	<1	<1	5	4600	5500	<50	<500
59	72	<5	5	<1	<1	<1	<1	<5	1	<1	6	4500	5800	<50	<500
4,009	180	<5	37	<1	<1	<1	<1	<5	3	<1	6	3900	3900	<50	<500
8,102	350	<5	140	<1	<1	<1	<1	<5	5	<1	7	3300	2500	<50	<500
12,002	350	<5	170	<1	<1	<1	<1	<5	8	<1	11	2900	2000	<50	<500
15,998	800	50	320	<1	<1	<1	<1	<5	24	<1	<1	3200	2400	<50	<500
20,000	160	<5	180	<1	<1	<1	<1	<5	2	1	7	2100	600	<50	<500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	5	<1	<1	<1	<1	<1	<5	<1	<1	5	4600	5500	<50	<500
59	100	6	<1	<1	3	<1	<1	<5	4	<1	10	4500	5900	<50	<500
4,009	400	40	<1	<1	10	<1	<1	<5	59	<1	30	4600	5600	<50	<500
9,704	720	65	3	1	13	3	<1	<5	72	<1	40	4600	5600	<50	<500
12,002	690	75	5	3	16	4	<1	<5	75	<1	50	4700	5800	300	<500
15,998	1200	72	3	2	12	4	<1	<5	80	<1	35	4600	5200	400	<500
20,000	1300	75	3	<1	11	3	<1	<5	64	<1	55	4600	4800	450	<500

TABLE 43

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 4J2695 **Lubricant No: CCL-G-150**

Transmission

Mileage	Metal *Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	<50	<50	<500
54	52	<5	15	12	<1	<1	<1	<5	<1	<1	5	1200	<50	<50	<500
4,000	520	25	38	36	1	<1	<1	<5	58	<1	15	1600	<50	<50	<500
8,025	540	6	33	34	<1	<1	<1	<5	10	<1	13	1400	<50	<50	<500
11,993	580	<5	27	32	5	<1	<1	<5	9	<1	5	1600	<50	<50	<500
16,034	1200	6	31	36	<1	<1	<1	<5	32	<1	12	1400	<50	<50	<500
20,000	190	<5	9	21	<1	<1	<1	<5	3	<1	10	1200	<50	<50	<500

Transfer Gear

Mileage	Metal *Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	<50	<50	<500
54	16	<5	8	1	<1	<1	<1	<5	7	<1	25	1300	<50	<50	<500
4,000	85	<5	21	12	<1	<1	<1	<5	2	<1	10	1300	<50	<50	<500
8,025	240	<5	23	16	<1	<1	<1	<5	1	<1	15	1400	<50	<50	<500
11,993	240	<5	12	14	1	<1	<1	<5	1	<1	6	1500	<50	<50	<500
16,034	120	18	8	<1	11	<1	<1	<5	4	<1	3	500	<50	<50	<500
20,000	280	<5	8	10	<1	<1	<1	<5	2	<1	15	1400	<50	<50	<500

Rear Axle

Mileage	Metal *Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1300	<50	<50	<500
54	11	<5	<1	<1	<1	<1	<1	<5	8	<1	18	1300	<50	<50	<500
4,000	130	7	<1	3	2	<1	<1	<5	60	<1	50	1600	<50	<50	<500
8,025	230	5	1	4	10	1	1	5	30	1	40	1400	<50	<50	<500
11,993	240	5	1	3	15	1	1	5	24	1	30	1600	<50	<50	<500
16,034	340	5	1	5	14	1	1	5	52	1	50	1400	<50	<50	<500
20,000	120	<5	1	<1	<1	<1	<1	<5	6	<1	25	1400	<50	<50	<500

TABLE 44

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 4J4623 **Lubricant No: CCL-G-151**

Transmission

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
61	37	<5	7	<1	<1	<1	<1	<5	<1	<1	7	1400	<50	<50	<500
4,000	290	<5	17	3	<1	<1	<1	<5	9	<1	16	1700	<50	<50	<500
7,956	400	<5	18	3	<1	<1	<1	<5	8	<1	18	1600	<50	<50	<500
12,000	450	<5	21	3	<1	<1	<1	<5	6	<1	18	1700	<50	<50	<500
15,960	405	<5	23	3	<1	<1	<1	<5	15	<1	7	1700	<50	<50	<500
20,000	310	<5	20	1	<1	<1	<1	<5	15	<1	40	1700	<50	<50	<500

Transfer Gear

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
61	97	<5	2	3	<1	<1	<1	<5	<1	<1	8	1400	<50	<50	<500
4,000	240	<5	17	5	<1	<1	<1	<5	28	<1	20	1700	<50	<50	<500
7,956	308	<5	29	3	<1	<1	<1	<5	4	<1	20	1600	<50	<50	<500
12,000	425	<5	20	4	<1	<1	<1	<5	7	<1	15	1500	<50	<50	<500
15,960	390	<5	27	4	<1	<1	<1	<5	20	<1	5	1400	<50	<50	<500
20,000	310	<5	14	1	<1	<1	<1	<5	1	<1	15	1200	<50	<50	<500

Rear Axle

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
0	<1	<5	<1	<1	<1	<1	<1	<5	<1	<1	10	1500	<50	<50	<500
61	48	<5	2	1	6	<1	<1	<5	10	<1	20	1400	<50	<50	<500
4,000	190	<5	2	3	46	<1	<1	<5	70	<1	60	1600	<50	<50	<500
7,956	420	6	<1	<1	55	<1	<1	<5	140	<1	63	1600	<50	<50	<500
12,000	440	8	<1	4	60	<1	<1	<5	135	<1	65	1600	<50	<50	<500
15,960	490	5	<1	6	68	<1	<1	<5	200	<1	40	1700	<50	<50	<500
20,000	530	10	<1	<1	68	<1	<1	<5	190	<1	90	1700	<50	300	<500

TABLE 45

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 5E5775 **Lubricant No: CCL-G-149**

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	8	1700	< 50	< 50	< 500
93	30	12	10	2	< 1	< 1	< 1	< 5	1	< 1	10	1700	150	< 50	< 500
3,910	440	26	12	7	< 1	< 1	< 1	< 5	1	< 1	12	1900	< 50	< 50	< 500
12,010	520	32	19	10	< 1	< 1	< 1	< 5	13	< 1	10	1900	< 50	< 50	< 500
14,095	520	26	15	7	< 1	< 1	< 1	< 5	1	< 1	17	1900	< 50	< 50	< 500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	8	1700	< 50	< 50	< 500
93	75	< 5	17	< 1	10	< 1	< 1	< 5	28	< 1	60	1700	< 50	< 50	< 500
3,910	490	< 5	36	2	62	< 1	< 1	< 5	100	< 1	80	1900	< 50	< 50	< 500
12,010	800	< 5	64	2	62	2	< 1	< 5	130	< 1	60	1800	< 50	< 50	< 500
14,095	880	< 5	69	1	25	3	< 1	< 5	25	< 1	85	1900	< 50	< 50	< 500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	8	1700	< 50	< 50	< 500
93	60	< 5	22	2	11	< 1	< 1	< 5	17	< 1	30	1500	< 50	< 50	< 500
3,910	280	8	180	5	16	< 1	< 1	< 5	120	< 1	50	1900	< 50	< 50	< 500
12,010	320	18	280	3	68	< 1	< 1	< 5	60	< 1	50	1600	150	< 50	< 500
14,095	530	22	800	2	100	< 1	< 1	< 5	100	< 1	65	2000	200	250	< 500

TABLE 46

METAL CONCENTRATIONS OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 5E5774 **Lubricant No: CCL-G-148**

Transmission

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	5	4600	5500	< 50	< 500
99	110	10	12	< 1	< 1	< 1	< 1	< 5	< 1	< 1	5	4500	5900	< 50	< 500
4,007	270	54	28	1	< 1	< 1	< 1	< 5	5	< 1	20	4600	5100	< 50	< 500
8,090	320	57	47	< 1	< 1	< 1	< 1	< 5	10	< 1	5	4400	5800	< 50	< 500
12,674	10	28	42	< 1	< 1	< 1	< 1	< 5	1	< 1	5	3900	3600	< 50	< 500
16,001	425	57	50	< 1	< 1	< 1	< 1	< 5	3	< 1	10	4600	5000	< 50	< 500
17,451	470	62	50	< 1	< 1	< 1	< 1	< 6	2	< 1	10	4600	5000	< 50	< 500

Transfer Gear

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	5	4600	5500	< 50	< 500
99	110	<5	23	< 1	< 1	< 1	< 1	< 5	6	< 1	13	4600	6100	< 50	< 500
4,007	200	<5	98	1	3	1	< 1	< 5	36	< 1	40	4500	5100	< 50	< 500
8,090	900	<5	224	< 1	3	5	< 1	< 5	17	< 1	7	4200	4800	< 50	< 500
12,674	110	<5	140	< 1	< 1	< 1	< 1	< 5	7	< 1	6	4000	3100	< 50	< 500
16,001	1130	<5	154	< 1	< 1	8	< 1	< 5	25	< 1	10	4500	5100	< 50	< 500
17,451	1040	<5	130	< 1	< 1	6	< 1	< 6	16	< 1	10	4600	3900	< 50	< 500

Rear Axle

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	12	<5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	5	4600	5500	< 50	< 500
99	100	10	29	< 1	< 1	< 1	< 1	< 5	7	< 1	7	4700	6100	< 50	< 500
4,007	200	25	300	< 1	< 1	< 1	< 1	< 5	14	< 1	35	4700	5800	< 50	< 500
8,090	300	45	560	< 1	28	< 1	< 1	< 5	17	< 1	20	4408	5900	350	< 500
12,674	320	52	760	< 1	40	< 1	< 1	< 5	36	< 1	50	4500	4900	600	< 500
16,001	400	50	680	< 1	38	< 1	< 1	< 5	18	< 1	80	4700	5000	800	< 500
17,451	390	54	720	< 1	34	< 1	< 1	< 5	16	< 1	55	4600	4800	700	< 500

TABLE 47

METAL CONCENTRATION OF IN-SERVICE GEAR LUBRICANTS

Vehicle No: 5E5776 Lubricant No: CCL-G-150

Transmission

	Metal														
Mileage	*Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1300	< 50	< 50	< 500
90	20	< 5	9	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1400	< 50	< 50	< 500
4,013	50	8	21	< 1	< 1	< 1	< 1	< 5	2	< 1	7	1400	< 50	< 50	< 500
7,930	90	12	24	2	< 1	< 1	< 1	< 5	3	< 1	5	1300	< 50	< 50	< 500
11,890	95	7	20	1	1	< 1	< 1	< 5	3	< 1	3	1500	< 50	< 50	< 500
16,199	92	7	15	< 1	< 1	< 1	< 1	< 5	2	< 1	10	1400	< 50	< 50	< 500
20,152	140	10	18	< 1	< 1	< 1	< 1	< 5	10	< 1	8	1500	< 50	< 50	< 500

Transfer Gear

	Metal														
Mileage	*Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1300	< 50	< 50	< 500
90	32	< 5	27	< 1	1	< 1	< 1	< 5	3	< 1	54	1400	< 50	< 50	< 500
4,013	200	< 5	50	< 1	1	< 1	< 1	< 5	7	< 1	11	1400	< 50	< 50	< 500
7,930	450	< 5	60	< 1	1	< 1	< 1	< 5	18	< 1	3	1500	< 50	< 50	< 500
11,890	360	< 5	46	< 1	2	< 1	< 1	< 5	3	< 1	1	1400	< 50	< 50	< 500
16,199	210	< 5	33	< 1	< 1	< 1	< 1	< 5	3	< 1	10	1500	< 50	< 50	< 500
20,152	320	< 6	54	< 1	< 1	< 1	< 1	< 5	7	< 1	7	1500	< 50	< 50	< 500

Rear Axle

	Metal														
Mileage	*Fe*	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1300	< 50	< 50	< 500
90	22	< 5	32	< 1	< 1	< 1	< 1	< 5	3	< 1	27	1400	< 50	< 50	< 500
4,013	130	< 5	170	< 1	11	< 1	< 1	< 5	20	< 1	40	1300	< 50	< 50	< 500
7,930	120	< 5	240	< 1	10	< 1	< 1	< 5	5	< 1	120	1300	< 50	< 50	< 500
11,890	310	< 5	340	< 1	38	< 1	< 1	< 5	20	< 1	70	1700	< 50	< 50	< 500
16,199	95	< 5	190	< 1	6	< 1	< 1	< 5	1	< 1	13	1300	< 50	< 50	< 500
20,152	450	12	880	< 1	48	< 1	< 1	< 5	19	< 1	90	1700	300	< 50	< 500

TABLE 48

METAL CONCENTRATIONS OF IN-SERVICE LUBRICANTS FROM M-151 TRANSMISSIONS

Vehicle No: 2J8600 Lubricant No: CCL-G-149

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	8	1700	< 50	< 50	< 500
64	54	< 5	8	< 1	2	< 1	< 1	< 5	4	< 1	10	1600	< 50	< 50	< 500
4,000	540	54	21	3	11	< 1	< 1	< 5	22	< 1	45	2000	< 50	< 50	< 500
8,001	640	40	38	4	16	< 1	< 1	< 5	33	< 1	35	1900	< 50	< 50	< 500
12,001	760	13	35	3	20	< 1	< 1	< 5	29	< 1	30	1900	< 50	< 50	< 500
15,955	840	18	28	4	14	< 1	< 1	< 5	25	< 1	20	2000	< 50	< 50	< 500
20,000	320	< 5	4	< 1	< 1	< 1	< 1	< 6	3	< 1	1	1800	< 50	< 50	< 500

Vehicle No.: 2J8645 Lubricant No.: CCL-G-150

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1300	< 50	< 50	< 500
56	13	< 5	6	< 1	1	< 1	< 1	< 5	2	< 1	6	1300	< 50	< 50	< 500
4,000	60	35	25	< 1	3	< 1	< 1	< 5	7	< 1	30	1400	< 50	< 50	< 500
7,988	780	22	62	3	10	< 1	< 1	< 5	29	< 1	90	1700	< 50	< 50	< 500
12,003	820	40	68	3	7	< 1	< 1	< 5	35	< 1	120	1500	< 50	< 50	< 500
16,093	1280	45	46	1	3	< 1	< 1	< 5	13	< 1	25	1300	< 50	< 50	< 500
20,000	780	10	46	< 1	5	< 1	< 1	< 5	19	< 1	30	1300	< 50	< 50	< 500

Vehicle No.: 2J8693 Lubricant No.: CCL-G-151

Mileage	Metal														
	Fe	*Pb*	*Cu*	*Cr*	*Al*	*Ni*	*Ag*	*Sn*	*Si*	*B*	*Na*	*P*	*Zn*	*Ca*	*Ba*
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	10	1500	< 50	< 50	< 500
71	14	< 5	9	< 1	3	< 1	< 1	< 5	5	< 1	6	1300	< 50	< 50	< 500
4,000	95	55	17	< 1	10	< 1	< 1	< 5	15	< 1	30	1600	< 50	< 50	< 500
8,171	920	57	44	7	30	< 1	< 1	< 5	60	< 1	35	1700	< 50	< 50	< 500
11,998	880	21	46	5	26	< 1	< 1	< 5	45	< 1	25	1800	< 50	< 50	< 500
16,203	1120	22	44	6	25	< 1	< 1	< 5	65	< 1	20	1800	< 50	< 50	< 500
19,952	530	5	24	2	10	< 1	< 1	< 5	23	< 1	10	1600	< 50	< 50	< 500

Table 48

METAL CONCENTRATIONS OF IN-SERVICE LUBRICANTS FROM M-151 TRANSMISSIONS (Cont'd)

Vehicle No.: 2J8666 **Lubricant No.: CCL-G-149**

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
	Metal														
0	< 1	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	8	1700	< 50	< 50	< 500
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4,000	580	110	15	5	9	< 1	< 1	< 5	14	< 1	50	1900	< 50	< 50	< 500
8,027	750	12	28	5	15	< 1	< 1	< 5	29	< 1	40	2100	150	< 50	< 500
12,005	940	30	26	4	12	< 1	< 1	< 5	27	< 1	50	2100	150	< 50	< 500
15,190	1140	14	24	3	10	< 1	< 1	< 5	39	< 1	13	1900	100	< 50	< 500
20,000	840	10	23	5	10	< 1	< 1	< 5	27	< 1	13	2100	100	< 50	< 500

Vehicle No.: 2J8669 **Lubricant No.: CCL-G-148**

Mileage	Fe	Pb	Cu	Cr	Al	Ni	Ag	Sn	Si	B	Na	P	Zn	Ca	Ba
	Metal														
0	12	< 5	< 1	< 1	< 1	< 1	< 1	< 5	< 1	< 1	5	4600	5500	< 50	< 500
63	100	< 5	4	< 1	< 1	< 1	< 1	< 5	1	< 1	7	4500	6100	< 50	< 500
4,000	160	8	12	< 1	< 1	< 1	< 1	< 5	5	< 1	20	4400	5000	< 50	< 500
8,000	3,250	18	42	5	2	11	< 1	< 5	11	< 1	12	4300	4500	< 50	< 500
11,927	5,080	25	40	5	3	10	< 1	< 5	17	< 1	13	4400	4700	< 50	< 500
16,095	> 16,000	18	44	5	3	9	< 1	6	16	< 1	2	4300	4400	< 50	< 500
20,000	5,000	20	52	9	5	15	< 1	< 5	21	< 1	< 1	4800	5200	< 50	< 500

APPENDIX III

TEMPERATURE DATA

TABLE 1. SUMMARY OF PEAK TEST AND OPERATING TEMPERATURES OF FIVE 1/4-TON M151 TRUCKS AT 85° TO 95°F AMBIENT TEMPERATURES

Location	Temperature, °F			
	Peak	Maximum	Mean	Minimum
Water	212	189	186	181
Oil Gallery	230	221	220	218
Transmission	228	209	197	191
Transfer				
Front Axle	180	178	172	168
Rear Axle	265	246	231	223
Brake Cylinders	120	–	–	–
Wheel Bearings	120	–	–	–

TABLE 2. SUMMARY OF PEAK TEST AND OPERATING TEMPERATURES OF TWO 3/4-TON M37B1 TRUCKS AT 85° TO 95°F AMBIENT TEMPERATURES

Location	Temperature, °F			
	Peak	Maximum	Mean	Minimum
Water	196	195	193	191
Oil Gallery	235	235	233	230
Transmission	170	170	148	126
Transfer	256	256	253	250
Front Axle	181	181	175	168
Rear Axle	223	223	222	221
Brake Cylinders	120	–	–	–
Wheel Bearings	120	–	–	–

TABLE 3. SUMMARY OF PEAK TEST AND OPERATING TEMPERATURES OF FIVE 1-1/4-TON M715 TRUCKS AT 85° TO 95°F AMBIENT TEMPERATURES

Location	Temperature, °F			
	Peak	Maximum	Mean	Minimum
Water	208	201	196	191
Oil Gallery	229	219	214	209
Transmission	190	158	154	143
Transfer	264	262	249	237
Front Axle	165	162	148	104
Rear Axle	219	216	210	202
Brake Cylinders	<120	–	–	–
Wheel Bearings	<120	–	–	–

TABLE 4. SUMMARY OF PEAK TEST AND OPERATING TEMPERATURES OF FIVE 2-1/2-TON M35A2 TRUCKS AT 85° TO 95°F AMBIENT TEMPERATURES

Location	Temperature, °F			
	Peak	Maximum	Mean	Minimum
Water	192	189	184	175
Oil Gallery	201	197	187	176
Oil Sump	207	204	198	193
Transmission	198	198	193	189
Transfer	235	234	2	217
Front Axle	127	126	118	101
Intermediate Axle	179	170	161	149
Rear Axle	170	170	158	148
Fuel to Engine	124	124	123	122
Return Fuel	129	129	127	123
Brake Cylinders	145			
Wheel Bearings	<120	–		

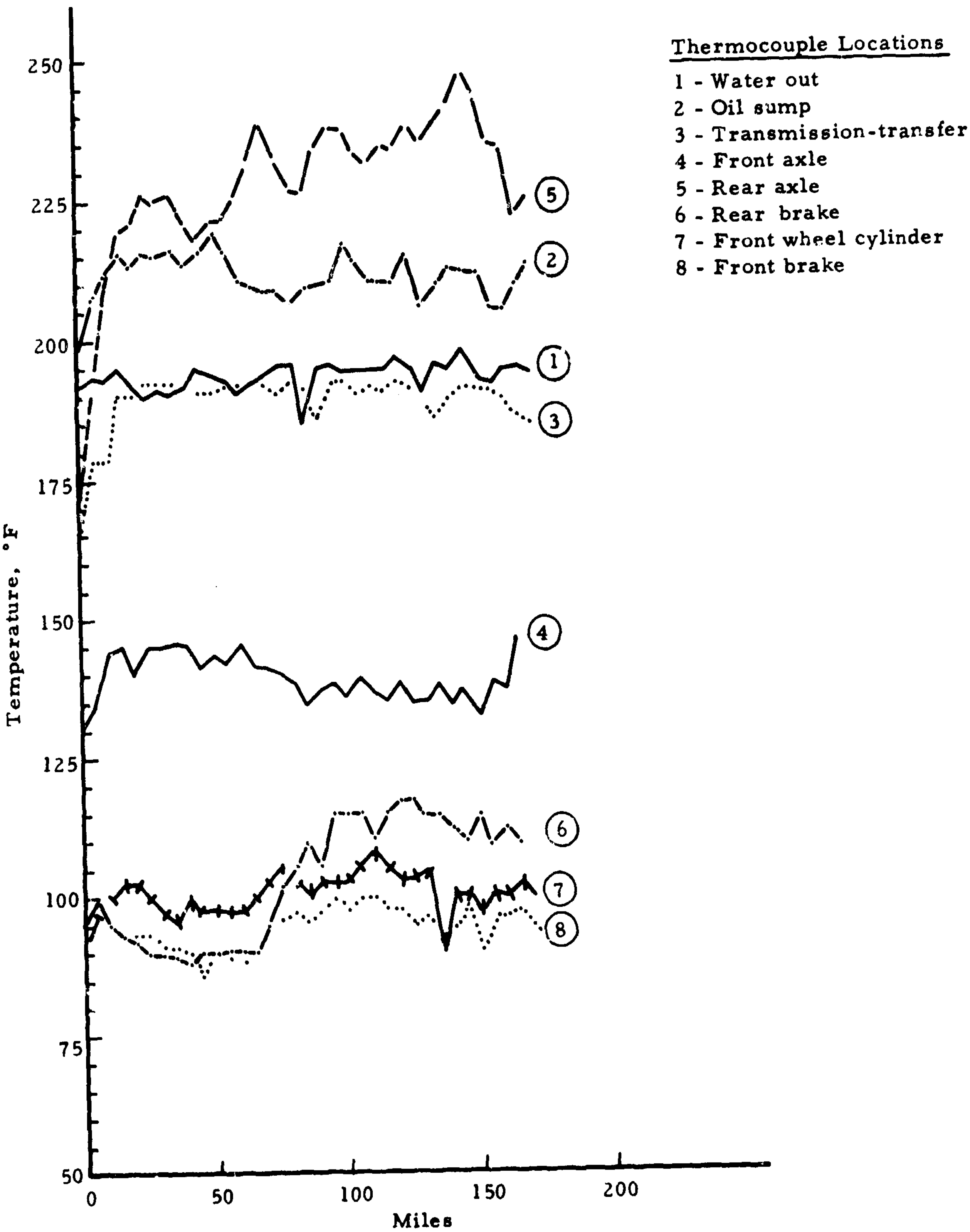
TABLE 5. SUMMARY OF PEAK TEST AND OPERATING TEMPERATURES OF THREE 5-TON M54A2 TRUCKS AT 85° TO 95°F AMBIENT TEMPERATURES

Location	Temperatures, °F			
	Peak	Maximum	Mean	Minimum
Water	200	197	194	189
Oil Gallery	215	202	201	199
Oil Sump	234	209	205	200
Transmission	249	200	196	193
Transfer	205	205	203	199
Front Axle	149	149	133	105
Intermediate Axle	106	176	167	145
Rear Axle	212	184	180	177
Fuel to Engine	118	103	103	–
Return Fuel	126	125	124	–
Brake Cylinders	150	–	–	–
Wheel Bearings	<120	–	–	–

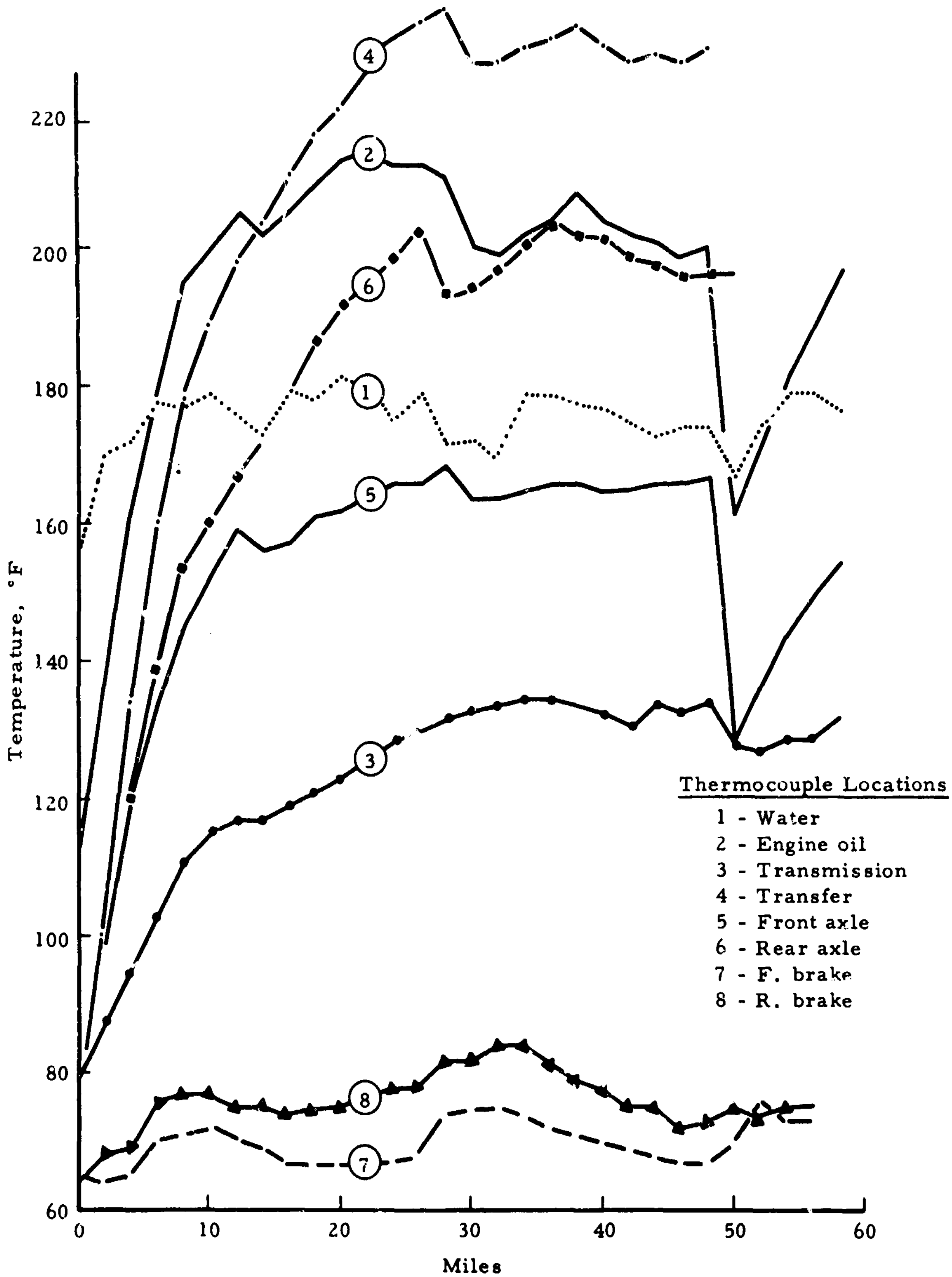
TABLE 6. AVERAGE MAXIMUM AXLE TEMPERATURES, °F AT 85° TO 90°F AMBIENT

		Intermediate Axle	Rear Axle
5-Ton	5E-5774	176	177
	5E-5775	185	180
	5E-5776	180	184
2-1/2-Ton	4J-2578	170	148
	4J-4623	169	170
	4J-2695	157	151
	4J-2594	159	160
	4J-4609	157	179
1-1/4-Ton	3F-3199	-	213
	3F-3078	-	216
	3F-3175	-	205
	3F-3072	-	214
	3F-3183	-	202
3/4-Ton	3B-3632	-	221
	3G-6207	-	223
1/4-Ton	2J-8669	-	224
	2J-8645	-	236
	2J-8600	-	223
	2J-8693	-	228
	2J-8666	-	246

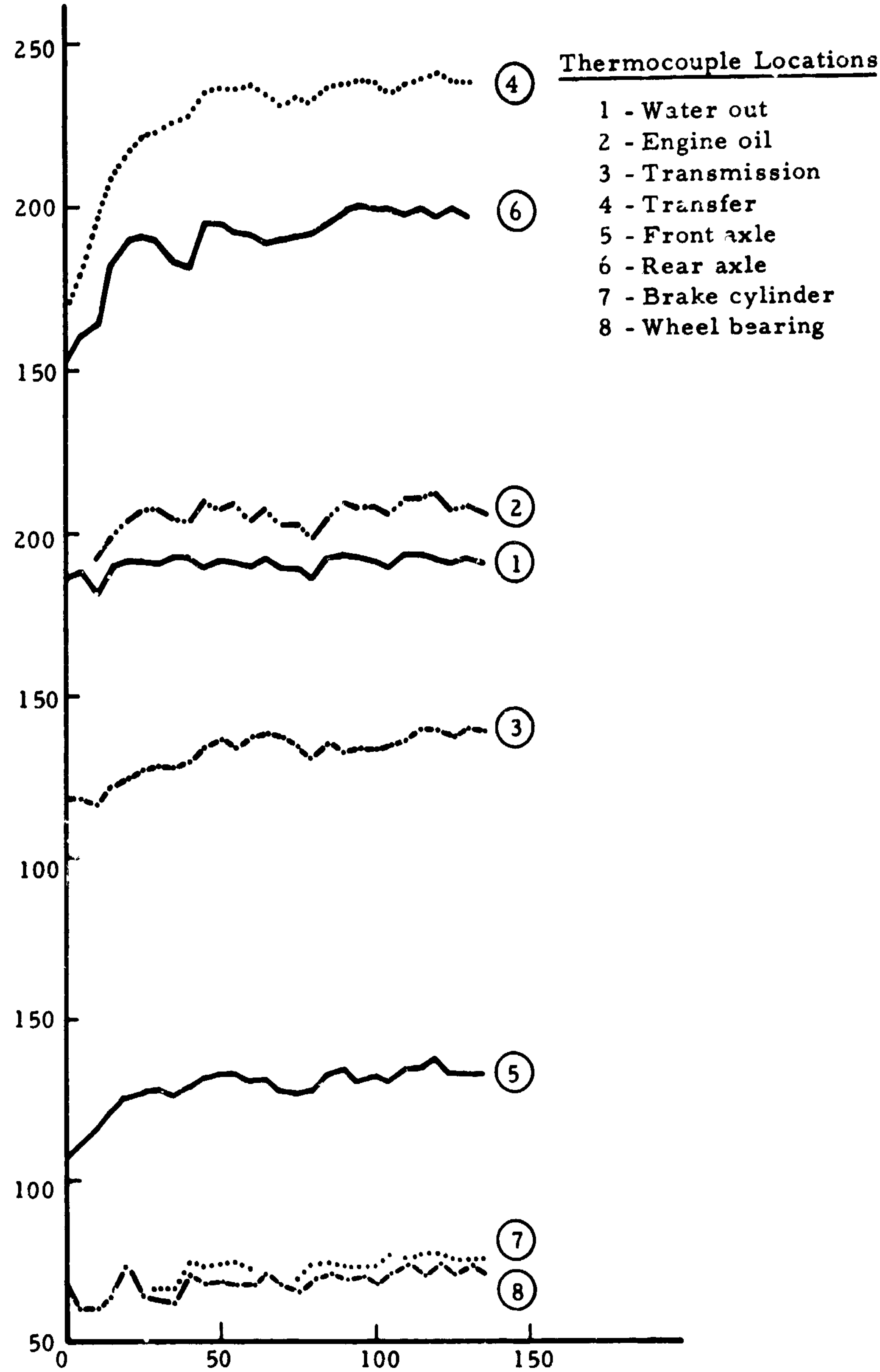
TYPICAL PLOT OF OPERATING TEMPERATURES AS
M151 TRUCK 2J8669 TRAVERSES TEST COURSE



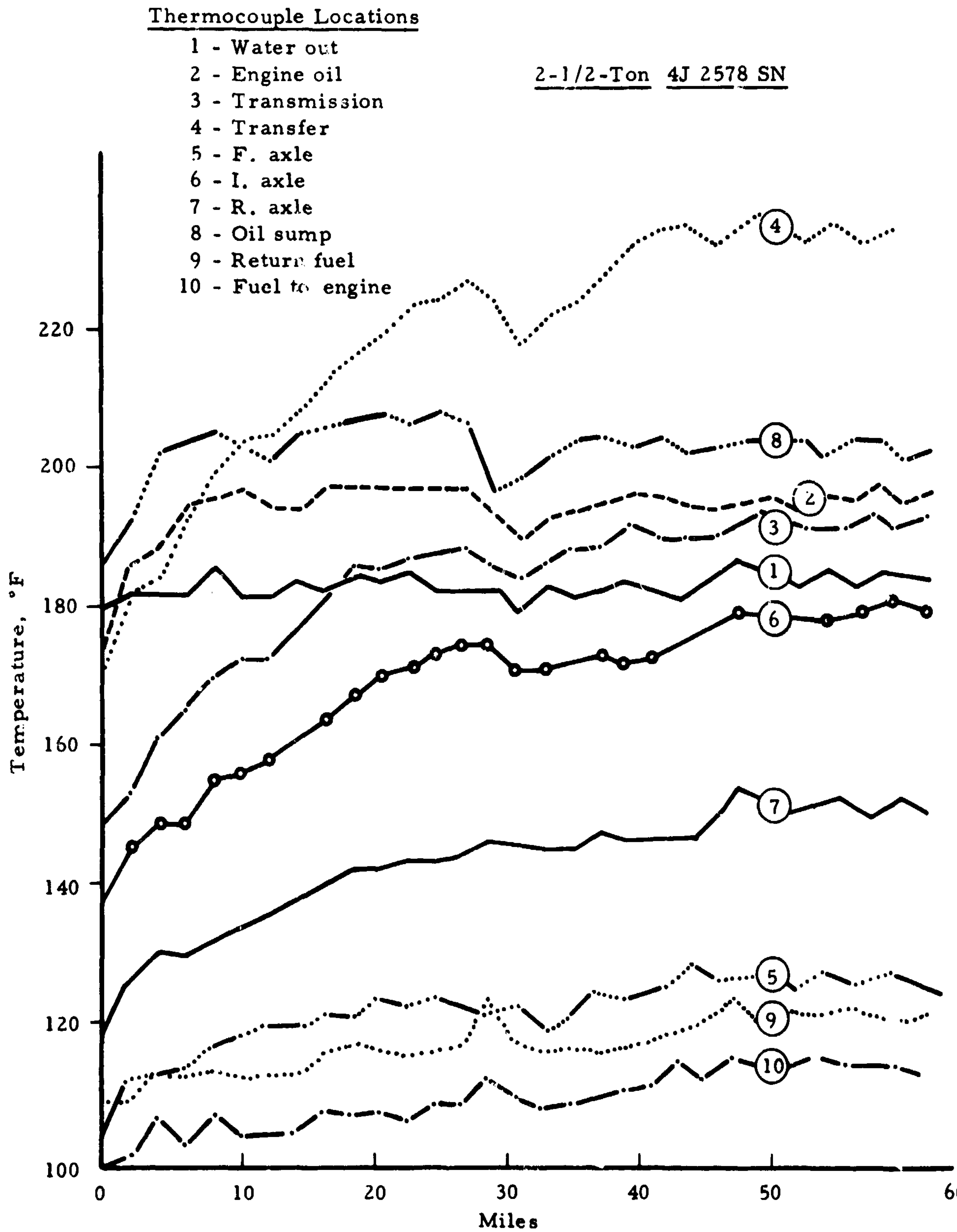
TYPICAL PLOT OF OPERATING TEMPERATURES AS
M37B1 TRUCK 3G6207 TRAVERSES TEST COURSE



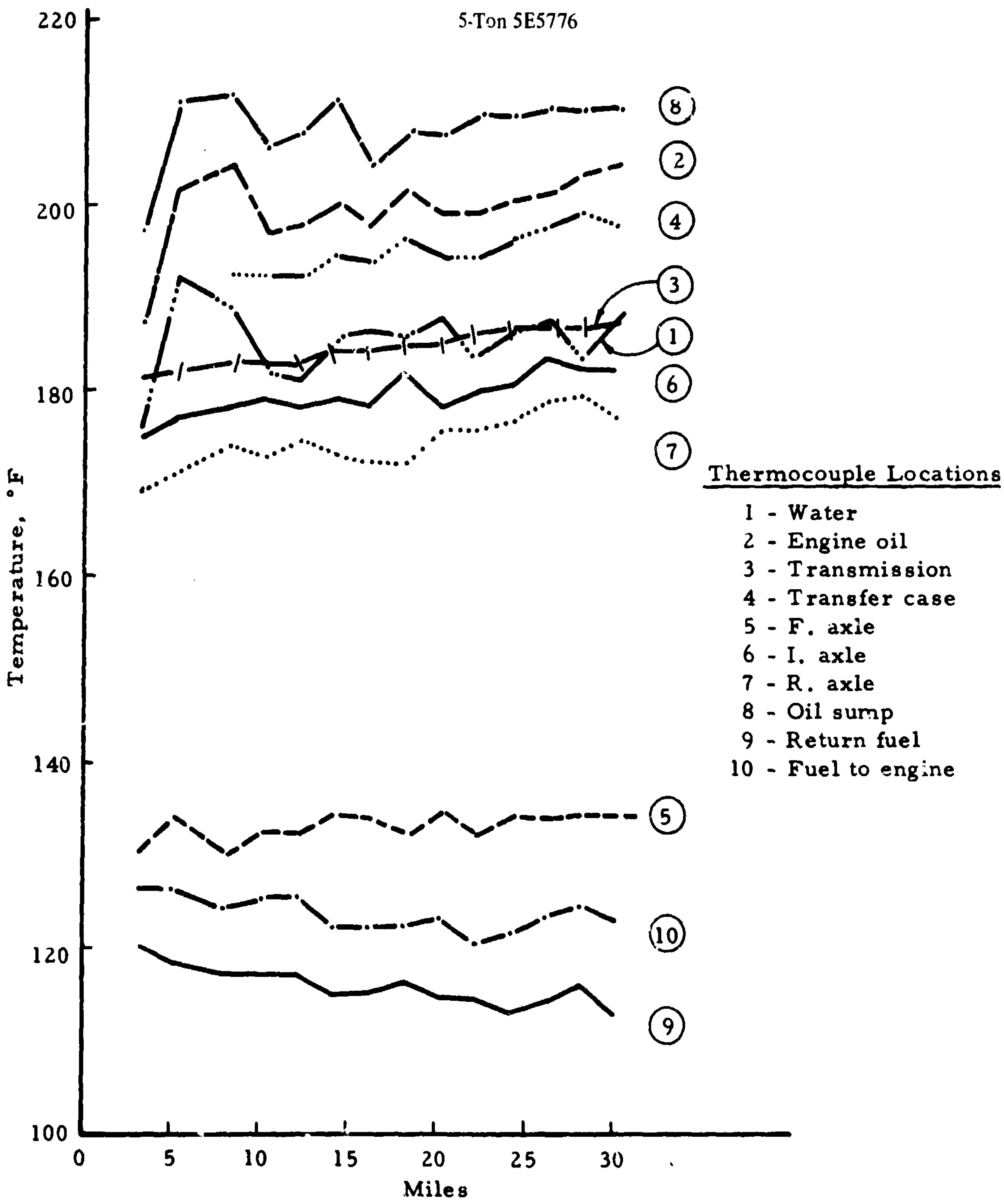
TYPICAL PLOT OF OPERATING TEMPERATURES AS
M151 TRUCK 3F199 TRAVERSES TEST COURSE



TYPICAL PLOT OF OPERATING TEMPERATURES AS
M35A2 TRUCK 4J2578 TRAVERSES TEST COURSE



TYPICAL PLOT OF OPERATING TEMPERATURES AS
M54A2 TRUCK 5E5776 TRAVERSES TEST COURSE



APPENDIX IV

DESCRIPTION OF UNSCHEDULED MAINTENANCE

UNSCHEDULED MAINTENANCE

Failure Category	Miles	Repairs
		Jeep 2J8600
Engine	2,575	Engine missed. The No. 3 intake valve push rod had come off the rocker. It was repaired and all tappets checked.
Engine	4,007	Engine missed. No. 3 intake valve push rod came off the rocker again. It was repaired and all tappet clearances checked.
Drive Line	9,152	All U-joints tightened.
Engine	10,019	New seal made for dipstick – the old one came loose and was lost.
Drive Line	16,254	Replaced left rear axle outboard U-joint and companion flange on rear output shaft of transfer. The U-joint broke in the middle of the cross and was considered a metallurgical failure unrelated to the lubricant. The companion flange was lost in towing the vehicle with the drive shaft removed. The transfer case was filled with fresh oil.
Drive Line	17,694	All U-joints tightened.
Engine	18,093	Replaced points, condenser, coil, and light in tachograph.
		Jeep 2J8645
Engine	10,735	Repaired oil gallery sample valve.
Drive Line	19,335	Rear axle failed. New driver recorded 450°F axle temperature and did not stop. Test on this truck was terminated.
		Jeep 2J8666
Engine	10,874	Adjusted carburetor idle. Installed a new oil pressure sending unit. The old one was broken in modifying the oil gallery sample tamp.
Electrical	10,874	Installed a new left headlight.
Engine	12,235	Gas mileage a little lower than the other Jeeps. Timing was checked, new spark plugs and new intake manifold gaskets were installed. The diaphragm in the carburetor was cracked and leaking and no repair kit was available. A new carburetor was installed. Compression was very satisfactory.
Engine	15,910	Rechecked ignition timing and distributor advance curve. The curves on 2J8669 (the most economical Jeep) and 2J8666 (which had the lowest economy) were identical except for a 1.5° difference at the high end.
Engine	18,774	Replaced fan belts and a bolt which had vibrated loose and dropped out of the rear generator mount. The exhaust manifold was warped and cracked at the "T-neck" and the part attached to the head had slid back about 1/4 inch. This was repositioned to approximately its original location.
Drive Line	19,026	Tightened bolts on drive shafts.
		Jeep 2J8669
Drive Line	6,606	Repack front drive shaft U-joint. This joint was taken off for a mid-test axle inspection and the cups came off and got dirt in them.
Engine	9,464	Spark plugs were cleaned and regapped. The carburetor idle was adjusted.
Engine	9,557	A new gasket was installed between the exhaust manifold and the front pipe.

Failure Category	Miles	Repairs
		Jeep 2J8600 (Cont'd)
Engine	14,108	Reset points and adjusted carburetor idle.
Engine	18,469	New points installed. Rechecked timing.
Engine	19,175	Exhaust manifold had slid back about 1/4 in.; this was repositioned. Four of the Jeeps had this same condition.
		Jeep 2J8693
Electrical	3,276	Batteries ran down. Replaced voltage regulator.
Electrical	3,598	Batteries would not hold charge and were replaced with new ones.
Engine	7,0?3	Replaced bolt in generator mount and tightened fan belts.
Engine	11,000	Replaced missing rear generator mounting bolt.
Engine	13,046	Replaced bolt in generator mount.
Drive Line	15,346	Replaced U-joint on inner end of left rear wheel drive shaft. The cross broke and this was not considered to be related to the lubricant.
Drive Line	16,203	Tightened all drive shaft bolts.
Engine	17,808	Replaced points, spark plugs, checked timing, replaced leaking valve cover gasket, repaired distributor air vent line and replaced missing bolt at back of generator mount.
Engine	19,903	Intermittent miss developed. Replaced frayed wire in distributor.
		3/4-Ton Truck 3G6207
Electrical	223	Batteries overcharging and fuming. New voltage regulator installed.
Electrical	602	New left headlight installed.
Electrical	2,677	New brake pressure switch installed. The old one caused the application counter to over-count, apparently from internal arcing.
Engine	3,514	Replaced leaking fuel line between fuel pump and carburetor.
Speedometer	5,035	The speedometer drive gear in the transfer case was slipping on the upper rear output shaft. A shim was added to prevent this.
Engine	5,792	The No. 1 rod bearing failed. This engine was a rebuilt unit at the start of test with 0.010-in. undersize rod and main bearing journals and sleeved cylinder bores. The failure did not scratch or scar the crankshaft and measurements indicated the journals were round and straight. The No. 1 rod journal was only about 0.0095-in. undersize instead of a full 0.010 in., but the journal to bearing clearance was still well within specifications. Later opinion was that this was the most likely cause of the trouble. New rod bearings were installed and the test resumed.
Engine	6,994	The above repair did not last and the No. 1 rod bearing failed again–probably from the same cause. The journal was scored, so a new standard size crankshaft with new rod and main bearings was installed. A new No. 1 rod was also required.
Engine	8,582	Minor leak at oil filter fitting repaired. Oil lost was negligible.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		3/4-Ton Truck 3G6... (Cont'd)
Engine	9,801	Engine developed a miss. No. 1 cylinder had only 30-psi compression pressure. The No. 1 intake valve was replaced and the seat was ground. The other valves and tappet clearances were OK. The head was reinstalled without disturbing the deposits.
Engine	14,428	A new fuel and vacuum pump assembly was installed. The old unit had a bad diaphragm in the vacuum pump section.
Wheel Bearings	14,946.3	The right front wheel bearings failed. The drivers had been recording normal temperatures in the 70° to 80°F range and no noise has been reported. Cause of the failure is unknown. A used spindle and the bearing adjusting nuts were purchased and installed along with two new bearings and the inner seal. The bearings and C.V. joints were repacked. The brake system was not opened.
Engine	15,875	The engine developed a miss. Compression in the No. 4 cylinder was low. A new No. 4 intake valve and the reground No. 4 exhaust valve were installed and the seats were ground. All other valves and tappet clearances were OK.
Electrical	16,710	Ammeter indicated no charge. Replaced generator and cleaned and adjusted regulator points.
Engine	17,053	Repaired oil leak at fuel pump.
Engine	17,178	Engine developed a knock. The No. 5 rod bearing failed and scored the crankshaft. This journal was turned 0.040-in. undersize and all new rod bearings were installed. The main bearings were continued in service.
Electrical	17,474	The brake light switch was replaced.
Brakes	18,012	The brakes were adjusted and 1/4 pint of fluid added.
Engine	18,517	Tightened timing gear cover, fuel pump bolts, and replaced oil filter hoses to prevent oil leaks.
		3/4-Ton Truck 3B3632
Drive Line	54	Adjusted clutch.
Engine	528	Oil filter line leaked, both replaced.
Electrical	1,039	Installed new voltage regulator.
Engine	2,238	Tightened bolts at several locations to prevent oil leaks.
Engine	2,999	A new rubber O-ring installed in the oil pump to stop an oil leak.
Drive Line	3,501	A new lower front output shaft seal and the seal retainer gasket were installed in the transfer case to stop a leak.
Engine	4,950	Oil leak at filter repaired.
Engine	7,182	A new water pump was installed.
Engine	11,543	The replacement pump drawn from Army stock and installed at 7,182 miles failed; it developed a bad bearing and seal, causing it to leak. A new pump was purchased and installed.
Speedometer	17,413	The speedometer drive gear started to slip on the transfer case upper rear output shaft, causing improper speed and odometer operation. A shim was added to prevent this. This failure occurred in both 3/4-ton trucks.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		3/4-Ton Truck 3B3632 (Cont'd)
Electrical	18,532	Repaired loose ground wire on left headlight.
Engine	18,562	The engine developed a miss caused by low compression in the No. 1 cylinder. The No. 1 intake valve was replaced and the seat was ground. All other valves and tappet clearances were OK. The head was reinstalled without disturbing the combustion chamber deposits.
Engine	19,030	An oil filter line broke while the truck was being driven and 4 quarts of oil were quickly pumped out before the driver detected any trouble. A road call was made and oil was brought out to the truck and the filter line leak was repaired. Operation of the engine seemed satisfactory; however, 28 miles later a knock developed. The No. 3 rod bearing failed and scored the crankshaft. The No. 5 rod bearing evidenced high wear. Test on this truck was terminated.
		The engine oil had been drained and the rod bearings removed. The oil pan was temporarily reinstalled without washing any of the parts. The truck was parked for approximately 2 weeks while repairs on several other trucks were being made. When the engine was disassembled for inspection, the pan, crankshaft, and bottom of the cylinder bores were found to be rusted and this condition did not prevail when the rod bearing were first removed.
		1-1/4-Ton Truck 3F3072
Engine	1,169	Engine developed a miss. A defective (No. 5) spark plug lead was replaced.
Engine	10,003	Engine tuneup, new plugs, points, and condenser.
Trailer	11,411	A driver backed up improperly, jackknifed the trailer and bent the hitch. The hitch was straightened and repaired.
Engine	15,559	The choke stuck in the closed position and the truck would not start. The choke was freed-up.
		1-1/4-Ton Truck 3F3078
Fuel System	141	The hose on the fuel filler neck was deteriorated and cracked, causing it to leak. The truck was run with the tank only partially filled until a new hose could be obtained from the manufacturer. The new one was installed at 2,004 miles.
Steering	8,901	The steering wheel came loose and could be pulled up and down. The collar on the steering shaft above the U-joint was tightened in place.
Engine	10,001	Engine was tuned up.
Engine	18,138	Checked and reset ignition timing.
		1-1/4-Ton Truck 3F3175
Brakes	5,310	Adjusted front brakes and parking brake.
Speedometer	14,438.7	Speedometer cable broke and was replaced.
Engine	15,145.6	Engine was tuned up, new plugs, points, and condenser.
		1-1/4-Ton Truck 3F3183
Engine	4,092	Fan belts came off while the truck was being driven. The belts were retightened.
Engine	4,900	A second road call was made for this truck; the harmonic balance had come apart and was replaced with a new one and new fan belts.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		1-1/4-Ton Truck 3F3183 (Cont'd)
Engine	5,009	The engine developed a light knock which disappeared when the clutch was disengaged. This noise was caused by broken (special shoulder) bolts which hold the flywheel to the crankshaft. New ones were installed, together with a new rear main bearing seal.
		These three initial failures are believed to all have been related. Possibly the failing harmonic balancer may have wobbled enough to throw the fan belts off and induced torsional vibration which broke the flywheel bolts.
Electrical	5,709	The alternator was not charging. A new one was installed.
Steering	9,571	The steering wheel "squawked" when it was turned. This was repaired.
Brakes	10,226	Adjusted Brakes.
Drive Line	14,590	Front axle differential cover either ran into something or was struck by a large rock which caused a small dent. The ring gear then rubbed a hole in the cover which allowed the oil to run out and ruin the axle. A new axle assembly was installed, but the original C.V. joints, brakes, and wheel bearings were continued in service.
Engine	16,367	Replaced points and set timing. Spark plugs OK.
		1-1/4-Ton Truck 3F3199
Wheels	3,002	Drivers say front end wobbles or shimmies. Checked front wheel alignment, tire pressures, wheel bearing adjustment.
Engine	3,002	Exhaust smoke is blue part of the time (after idling). Compression check was OK and valve adjustment was OK. Valve deck runs quite wet and it was concluded that oil may be going down guides. Vacuum pump was dry and not pumping oil.
Electrical	3,215	Left stop light replaced.
Instruments	4,?35	The oil pressure gage was tightened in place in the instrument cluster panel.
Drive Line	5,085	The clutch disc failed. A new disc and pressure plate were installed.
Speedometer	5,221	A new speedometer cable was installed.
Engine	8,672	New spark plugs were installed.
Trailer	10,602	The trailer hitch was damaged from improper backings. It was straightened and repaired.
Chassis	14,244	The right rear shock absorber was broken loose. It was welded and repaired.
Engine	14,631	Engine was tuned up. New plugs and points were installed. Also, the gas tank attachments were tightened.
Electrical	16,999	Replaced a tail light bulb.
Drive Line	19,017	Tightened bolts on front and rear differential covers.
		2-1/2-Ton Truck 4J2578
Engine	3,676	Tightened valve covers to stop an oil leak.
Electrical	3,676	One new instrument light installed.
Engine	5,989	The sample valve installed in the oil gallery broke off (from fatigue induced by vibration) while the truck was en route to Padre Island. A new valve was installed and 14 quarts of oil added. The oil capacity is 22 quarts and this failure did not damage the engine.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		2-1/2-Ton Truck 4J2578 (Cont'd)
Engine	9,922	The No. 1 intake valve rocker arm bent and cracked next to the adjusting screw. A new rocker arm and push rod were installed. All tappet clearances checked OK.
Tires	10,313	Tires rotated.
Engine	15,004	New rear rocker arm cover gasket installed.
Brakes	15,004	Adjusted brakes.
Drive Line	16,902	Tightened bolts on intermediate axle drive shaft companion flanges. The front axle pinion seal leaks a little but not enough to warrant changing the seal.
		2-1/2-Ton Truck 4J2594
Electrical	1,168	The generator was replaced.
Wheels	2,890	A new lug bolt was installed on the left intermediate wheel.
Electrical	9,083	The voltage regulator was undercharging and was replaced with one we had adjusted.
Wheels	9,858	A stud broke on the right trailer wheel and was replaced with a new one. On the M105 trailers, the wheels do not fit on a center pilot and all radial loads are carried by the six lug bolts.
Tires	10,001	The tires were rotated.
Brakes	12,002	The brakes were adjusted and one ounce of fluid was added.
Electrical	14,669	Replaced turn signal flasher and tachograph light.
Brakes	14,669	Adjusted brakes.
Tires	17,365	Three new tires installed (both L.R. duals and R.F.).
		2-1/2-Ton Truck 4J2695
Drive Line	341	The right intermediate wheel leaked gear oil. A new drive flange gasket was installed.
Drive Line	4,343	The clutch failed. A new clutch disc and pressure plate were installed.
Electrical	8,795	The generator was replaced.
Brakes	8,795	Repaired air leak in line at the compressor.
Tires	10,001	Tires rotated
Engine	11,480	The truck suddenly developed a heavy knock as the vehicle was being driven approximately 40 mph along the flat high-speed course. The truck was towed to the Institute and the engine oil pan was removed for an inspection. The crankshaft was found to be broken. The engine was removed from the chassis and a new crankshaft was taken from a spare engine and installed along with a new No. 5 main bearing. All of the other used rod and main bearings were continued in service.
Engine	16,412	Installed new water temperature thermostat.
		2-1/2-Ton Truck 4J4609
Drive Line	187	New side cover gaskets installed on rear and intermediate axles
Drive Line	1,037	Left rear wheel leaking lubricant. Removed left rear wheel, cleaned and repacked bearings and installed new inner and outer seals.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		2-1/2-Ton Truck 4J4609 (Cont'd)
Brakes	4,000	Adjusted brakes.
Engine	4,000	A new sample valve was installed—the old one leaked a little. This truck gave a little lower fuel mileage than 4J2695, so injector timing was checked again. Both were OK.
Electrical	5,031	The generator and regulator were replaced.
Brakes	8,406	The left front wheel developed a leak where the brake hydraulic line attaches to the wheel cylinder. New copper washers were installed in this fitting and 1/2 pint of fluid was added to cover losses and in bleeding this cylinder. The brakes were adjusted again.
Engine	8,406	New rocker arm cover gaskets were installed.
Engine	9,198	Leak in accelerator arm cover on injector pump corrected by tightening screws.
Tires	9,918	Tires rotated.
Electrical	11,042	Tightened battery cable.
Brakes	13,347	Adjusted brakes.
Brakes	13,362	Installed new air-hydraulic boost cylinder, one pint of fluid, and adjusted brakes The previous brake adjustments may have been thought necessary when the actual trouble was in the boost cylinder.
		2-1/2-Ton Truck 4J4623
Wheels	1,067	Adjusted front wheel toe-in.
Wheels	2,641	Replaced six studs and nuts on left trailer wheel and one stud and nut on the right trailer wheel.
Drive Line	2,901	Replaced the upper rear output shaft seal in the transfer case.
Electrical	7,955	Generator not charging. Installed a readjusted voltage regulator.
Tires	9,754	Rotated tires.
Electrical	12,000	Trailer light cable broke and was repaired.
Electrical	12,490	Horn button assembly came apart and was repaired.
Electrical	12,677	The oil pressure gage failed. A substitute Ashcroft gage was connected to the oil gallery sample valve. Pressure was OK.
Brakes	15,694	Brakes were adjusted and bled. Air was reported to have been in the right front and left intermediate wheel cylinders. Eight ounces of fluid was added.
		5-Ton Truck 5E5774
Drive Line	209	A new gasket was put on rear axle top cover to stop an oil leak.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		5-Ton Truck 5E5774 (Cont'd)
Engine	748	The truck was being driven on the high-speed course with normal coolant and oil levels. The driver stopped at the turn-around point (after having driven approximately 50 miles) and shut the engine off. A few minutes later, the engine would not crank. The water-air manifold was found to have cracked internally and fed coolant into several cylinders, causing the engine to lock hydraulically after it was shut off. The rear head was noted to have developed hairline cracks between the intake and exhaust valve seats in all three cylinders. These, however, did not seem to leak. To repair this engine, a new dual head assembly completed with manifolds, valves, rocker shafts, etc., was removed from a spare LD-465-1A engine and installed. These parts are interchangeable between the LD and LDS engines. Since ethylene glycol had contaminated the oil, the engine was flushed and fresh oil put in. The oil filters were changed and fresh coolant added.
Electrical	816	A new starter was installed.
Drive Line	816	Rear axle side cover gasket replaced to stop a leak.
Electrical	1,107	Replaced two instrument light bulbs and one stop light bulb.
Brakes	1,107	Repaired brakes on trailer (non-test equipment).
Wheel Bearing	1,852	Right wheel leaking lubricant. The wheel was removed, cleaned, and the hub replaced with grease. A new inner seal was installed. Axle lube level was OK.
Electrical	1,852	Replaced left rear trailer tail light.
Electrical	2,270	Repaired loose battery cable and loose wire on starter.
Engine	3,771	Engine stop wire pulled out of collar on injection pump; engine would not stop. This was repaired.
Electrical	4,007	Replaced rear generator bolt.
Engine	4,155	No. 1 intake valve clearance less than specifications. Adjusted and checked all valves.
Drive Line	5,805	Installed new (bellows type) boots on inboard side of front wheel C.V. joints. The original ones were cracked and torn.
Engine	6,810	The pulley at the front of the crankshaft broke and damaged the fan. A new pulley, fan, and timing cover seal were installed.
Drive Line	7,256	Intermediate axle hubs leak lubricant. The hubs on both sides were cleaned, repacked, and new seals were installed.
Drive Line	8,090	Tightened bolts on companion flanges of jack shaft between transmission and transfer case.
Engine	8,411	Replaced two fan belts and adjusted air compressor belt.
Engine	9,175	Replaced tachometer angle drive on front of timing cover.
Engine	9,566	The front crankshaft pulley broke in a manner very similar to the failure at 6,810 miles. The hub of the pulley broke and then the pulley and retaining bolt at the front of the crankshaft unscrewed and came loose. A new pulley, harmonic balance, key, and bolt were installed with high-strength lock-tite on the threads. The failed pulley hub ruined the timing cover seal and wallowed out the hole in the timing cover, so a new timing cover was installed.

Failure Category	Miles	Repairs
		5-Ton Truck 5E5774 (Cont'd)
Engine	9,797	Fuel mileage dropped a little and the engine developed an intermittent miss. The truck was checked for fuel leakage, injector timing, and valve clearance The Nos. 1, 3, 4, and 5 intake and Nos. 2, 4, and 6 exhaust valve tappet clearances were below specifications. All valves were checked and adjusted.
Engine	10,068	The truck developed a miss and did not run satisfactorily. The Nos. 5 and 6 cylinders had low compression. On the previous day, the tappets had been adjusted and seven valves had been found to be tight. The valves were again found to be tight at 10,068 miles. Both heads were removed for inspection. The No. 5 exhaust valve had extruded and been drawn up into the valve port. The Nos. 4 and 6 exhaust valves had also been drawn part way into their ports. The rear head and valves were photographed to illustrate how this type failure progresses. The three exhaust valves demonstrated the failure in steps from the early stages to complete extrusion of the outer edge and contact face of the valve. This type failure seems to develop over a relatively short period of time and mileage and is understood to have been experienced by others who operate the M54A2. The combustion temperatures, pressures, and spring loadings are all very high in this engine, and these factors combine with the thinner than usual design of the valve head to contribute to this type failure. Use of heavier valves, which may extend below the gasket face of the head as in the 525-cu in. turbocharged Caterpillar 1673-B, with appropriate recesses machined in the pistons for clearance, might be worth investigating for alleviation of this problem. The valves in the front head also had begun to be drawn into the ports, although not to the extent of those in the rear head. In addition, the No. 5 exhaust valve push rod was bent and the edge of the precup in the No. 6 piston had eroded or burned away to a considerable extent. To repair this engine, two new heads with valves, springs, keepers, and manifolds were removed from our second spare LD-465-1A engine and installed. The original rocker arm assemblies and injectors were continued in service. A new No. 5 exhaust valve push rod was installed. The heads on this engine had been replaced at 748 miles, so the service life on these heads was 9,320 miles.
Brakes	12,638	Intermittently, the brake pedal could be pushed almost to the floor, but on a second stroke a normal high-pedal prevailed. The master cylinder was removed and disassembled for inspection. The cylinder was found to have a very small amount of sand in it and approximately a 5/8-in.-long section of the edge of the lip of the rubber cup on the piston assembly (63477-FO-6433A) was broken off. This piston and cup were replaced by one removed from an original equipment cylinder. During the repair the master cylinder was washed out with ethyl alcohol and refilled with fresh fluid. This, together with bleeding the wheel cylinders, effectively refilled the system with fresh fluid. The parking brake was also adjusted and the gas tank straps tightened.
Drive Line	12,727	The clutch failed. The disc was relined.
Brakes	13,035	The brakes again became intermittent. The air-hydraulic boost cylinder (a non-test item) was removed from 5E5775 (which was in the shop for a major repair), washed out with ethyl alcohol, installed on 5E5774, and filled with the proper fluid. No replacement cylinder was available, so the failed unit was sent to a local brake service company for overhaul.
Engine	14,025	The engine knocked. The pan was removed and the rod and main bearings were inspected. The thought was that one bearing might be failing and, if caught in time, could be replaced and further mileage accumulated. All of the bearings were judged reasonably serviceable so they were reinstalled. The original oil was poured back in the engine and test was resumed. These engines are noisy and it is sometimes uncertain whether the sounds denote impending failure.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		5-Ton Truck 5E5774 (Cont'd)
Winch	14,322	The drive shaft between the transmission and winch broke in half and dented the engine oil pan. This is a non-test item and the cause of failure is unknown. It appears as though the drive may have self-engaged while the truck was running along the road. The shaft was removed from the truck.
		5-Ton Truck 5E5775
Brakes	1,455	Adjusted parking brake.
Electrical	2,954	Replaced license plate light bulb on trailer.
Electrical	3,675	Replaced right rear marker light bulb.
Electrical	4,229	Replaced tachograph light bulb.
Engine	4,699	Tightened loose cap on side of injector pump which was leaking. This also seemed to affect a low-speed fuel knock.
Engine	5,030	Engine developed a light knock which would go away when the No. 6 injector fuel supply line was loosened. The pan was removed and the bearings inspected. All were serviceable so they were reinstalled and the pan refilled with the same oil which had been in use. Tappet clearances were checked and it was decided this was a characteristic sound. A missing bolt was also replaced on the rear generator mount and the exhaust stack was tightened.
Drive Line	5,798	Installed new (bellows type) boots on inboard side of front wheel C.V. joints. The original ones were cracked and torn.
Engine	5,798	Oil seeps out of relief slot in head gasket. This was not a serious leak and head gaskets were in such short supply that it was decided to tolerate this problem. The theory that it must come from a cracked rubber O-ring in the gasket later proved correct. This did not affect oil pressure or oil flow and current production gaskets do not have these O-rings anymore.
Electrical	7,021	Replaced left rear trailer light bulb.
Engine	7,286	The truck developed a knock in the engine. Operation immediately prior to this trouble had been on the flat road at approximately 40 mph and the oil (CCL-O-146) and coolant levels were proper. The oil pan was removed for an inspection which indicated the No. 5 rod bearing had failed and scored the crankshaft journal. The engine was removed from the chassis and a new crankshaft (removed from a new spare LE-465-1A engine) was installed, together with new rod and main bearings and a new connecting rod in the No. 5 cylinder. The used rod and main bearings were photographed. The rod was necessary because the failed bearings scored and abraded the lower end. Since it was necessary to remove the No. 5 piston to put the rod on, the rear head was taken off. The valves were removed from the head for inspection and the guides were found to be heavily worn. One of the heads, complete with valves and springs, removed from 5E5774 at 748 miles (when the water-air manifold cracked) was prepared by refacing and reseating the valves and was used in this repair. The excessive wear of the No. 5 rod bearing had allowed the piston to travel higher during its up-stroke than is normal and the piston top had struck a valve, although without apparent damage. The precups in the crowns of the Nos. 5 and 6 pistons had large open cracks at their edges and these were photographed. The No. 6 piston skirt was heavily scored and the compression rings on these two pistons were worn and had deposits on their faces. These pistons were photographed and returned to service. None of the others were removed, and all of the cylinder bores were in satisfactory condition.

UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		5-Ton Truck 5E5775 (Cont'd)
Engine (Cont'd)	7,286	The engine was reassembled without washing any of the parts. Metal debris remaining in the oil pan after the drain was picked out by hand. The coupling half, part number 2910-966-7393, which drives the injector pump had one stripped bolt hole in it and this piece (only) was replaced with one from a new pump. The old pump assembly continued in service. This coupling half does not have a key or keyway–just a tapered hole and a tapered shaft with a retaining nut–a rather unusual arrangement when you consider this is responsible for maintaining the injector pump in time, however, this did not cause trouble. The power steering pump drive shaft was noted to have slipped back while the engine ran, prior to this repair and the drive gear was slightly damaged from hitting the other timing gears. During disassembly, the shaft fell out of the power steering pump, probably from either omission or breakage of the snap ring. Since this was not a test item, a new power steering pump was installed. Several complete facing segments were broken from the clutch disc on the front and back, so a new clutch disc and pressure plate were installed. The replacement disc supplied under the original Federal stock number was a new Bendix cerametalix type with relatively few trapezoidal facings instead of a full set of radial segments. New oil filters were installed to minimize debris in the engine and a fresh change of oil was weighed into the engine.
Cooling System	7,515	Lower radiator hose leak was repaired and 3 gal of antifreeze were added. No heating problem had occurred, however.
Engine	8,148	The engine developed a miss and had low compression on the Nos. 5 and 6 cylinders. The rear head complete with valves and springs was replaced with one removed from 5E5774 at 748 miles. All valve clearances were checked and adjusted.
Drive Line	12,010	Bolts were tightened in all drive line companion flanges.
Electrical	12,841	Replaced a headlight.
Engine	13,189	The front head gasket was leaking oil to the outside of the engine. The front head was removed and a new gasket was installed. Oil got in the cooling system and antifreeze in the oil, so fresh oil was put in the engine and fresh antifreeze in the radiator.
Engine	13,935	Following the foregoing repair, the truck was driven to Padre Island and subjected to 200 miles of high-torque, all-wheel drive operation in the deep sand at a location known as "Little Shell," an area marked by a sign posted by the National Seashore Service as "four-wheel drive vehicles only." During this operation, the truck ran progressively poorer and high engine temperatures developed. Peaks of 215° water out, 230° oil gallery, and 250° in the oil sump were reported. Blowby became excessive and the exhaust smoked more than the usual amount. The truck was towed back from Padre Island. Compression in the No. 5 cylinder was only 30 psi. The rear head and pan were removed and the Nos. 5 and 6 pistons were taken out of the block. The No. 5 piston had a hole burned in the crown and the No. 6 piston had scored the skirt and cylinder liner. The precup areas of both pistons had large cracks and chips broken out of them. The No. 6 cylinder liner was cracked vertically and the rim at the top of the liner was cracked partially around the circumference. The No. 6 liner was pressed out with a hydraulic ram and a new liner was installed. Also, new Nos. 5 and 6 pistons were installed with the original used rings.

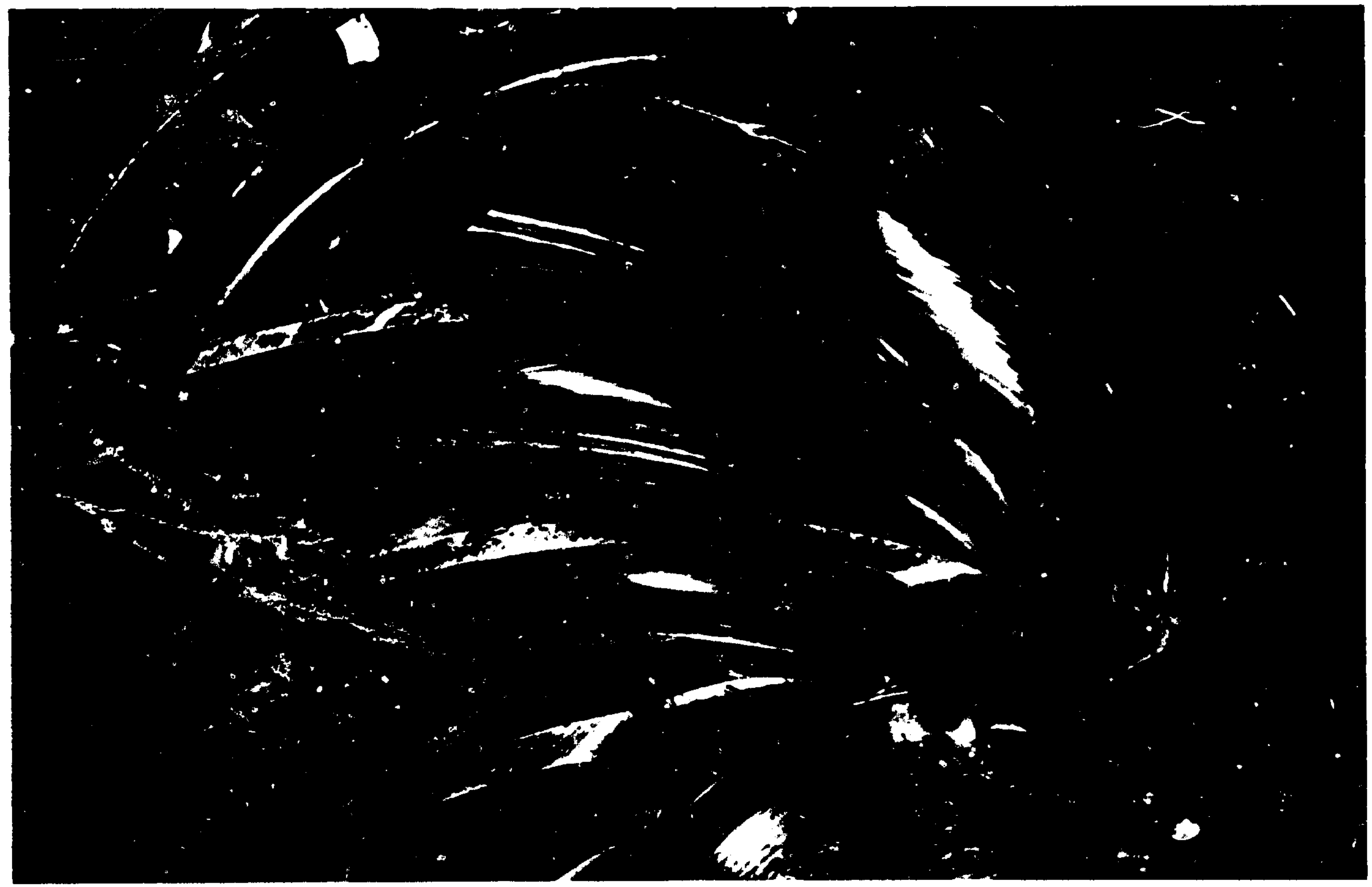
UNSCHEDULED MAINTENANCE (Cont'd)

Failure Category	Miles	Repairs
		5-Ton Truck 5E5775 (Cont'd)
Engine	14,073	After one trip on the test course, the truck consumed 2 gal of antifreeze and 20 lb of oil. The exhaust smoke was light grey. The heads and pan were removed for an inspection. Re-examination of the used No. 6 cylinder liner suggested the No. 6 bore might be leaking from a crack in the block. This was confirmed. A long vertical crack ran up the right (turbocharger) side of the No. 6 bore and this had been overlooked during the previous repair. The new liners are a push fit in the bores and the old liner had to be pressed out, so the new liner allowed large quantities of antifreeze to leak between the block and liner and to fall into the crankcase. Test was terminated on this truck.
		5-Ton Truck 5E5776
Electrical	2,998	Generator replaced.
Electrical	4,158	Signal light junction box partially failed and some wires burned. No replacement assembly available.
Engine	6,393	Tachometer broken. Replaced drive on front of timing cover.
Drive Train	7,024	Several jack shaft drive flange bolts loose. Lock washers were installed throughout.
Engine	7,432	The truck developed an intermittent sound of combustion explosions in the exhaust pipe. This was traced to a burned No. 6 exhaust valve which when rotated to a certain position caused this sound and was accompanied by a loud hissing sound of the exhaust gas escaping through the exhaust valve guide. The rear head was removed and inspection revealed that all of the valve guides were heavily worn and it would not be practical to reface and reseat the valves with the guides in such condition. Replace valves and guides were not available, so the head was replaced (complete with valves and springs) with one removed from 5E5774 at 748 miles (after the valves were refaced and reseated). All valve tappet clearances were checked.
Engine	7,705	Replaced a water manifold bolt and 3 gal of fresh antifreeze. Leak did not cause any heating problem.
Electrical	7,705	Replaced voltage regulator with one which was used but had been adjusted.
Electrical	8,599	The starter solenoid failed and was rebuilt.
Electrical	8,669	Replaced burned out left headlight.
Drive Line	11,057	The clutch was slipping and several of the segments on both the front and back of the clutch disc had large chips broken out of them. A new disc was installed.
Electrical	11,890	The starter solenoid failed and was replaced.
Brakes	11,890	The air line between the compressor and the air tanks chafed against the frame and developed a leak. A new line was installed.
Brakes	13,285	Adjusted brakes and checked tappets.
Fuel	14,090	[illegible] fuel line between fuel filter and injector pump.

Failure Category	Miles	Repairs
		5-Ton Truck 5E5776 (Cont'd)
Drive Line	15,288	Adjusted clutch pedal free play.
Electrical	17,923	Installed new stop light switch.
Engine	18,960	Replaced rear valve cover gasket to stop an oil leak.

APPENDIX V

GEAR PHOTOGRAPHS



PINION GEAR, DRIVE SIDE
1/4 TON, M151 #2J8600 REAR AXLE
CCL-G-149 20,000 mi.

PINION GEAR, DRIVE SIDE
1-1/4 TON, M715 #3F3175 REAR AXLE
CCL-G-149 20,000 mi.

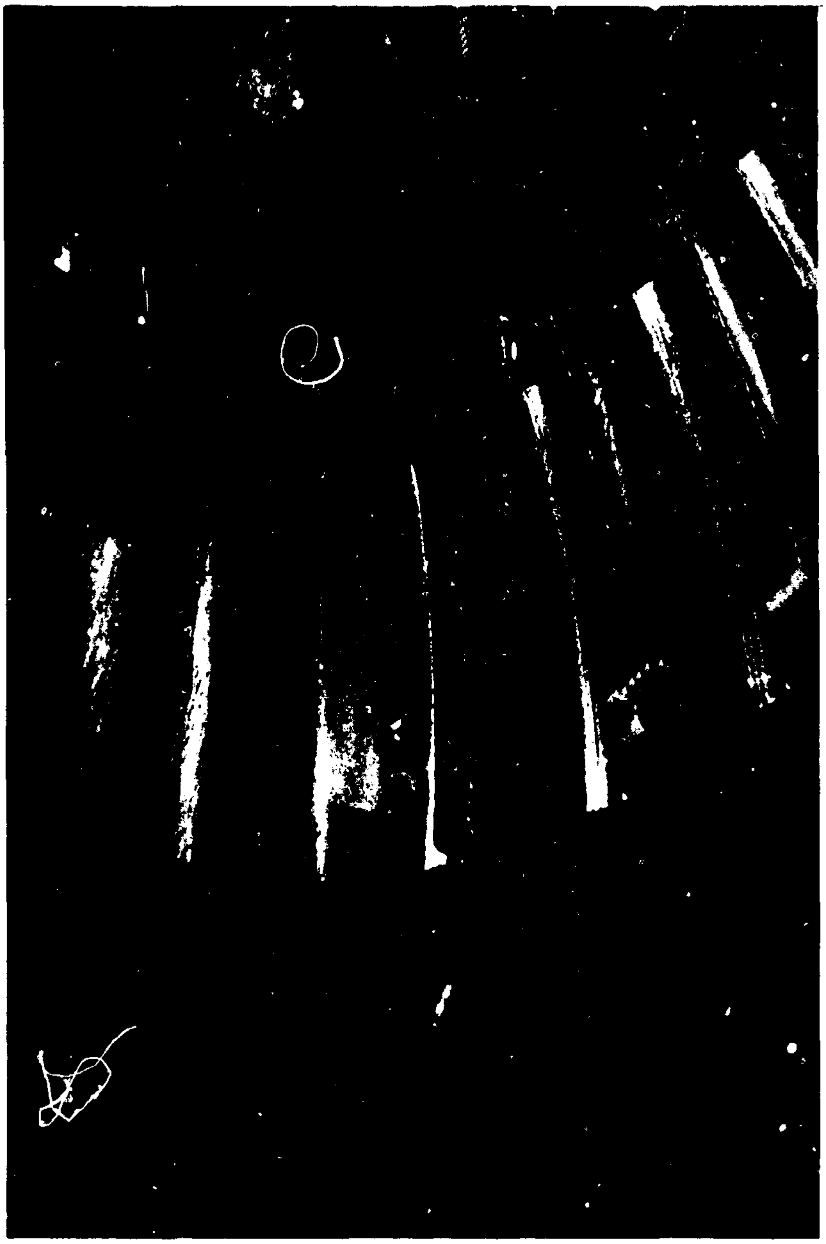
PINION GEAR, DRIVE SIDE
5 TON, M54A2 #5E5776 REAR AXLE
CCL-G-150 20,000 mi.

RING GEAR, DRIVE SIDE
1/4 TON, M151 #2J8600 REAR AXLE
CCL-G-149 20,000 mi.

PINION GEAR, DRIVE SIDE
1/4 TON, M151 #2J8666 REAR AXLE
CCL-G-149 20,000 mi.

RING GEAR, DRIVE SIDE
1/4 TON, M151 #2J8666 REAR AXLE
CCL-G-149 20,000 mi.

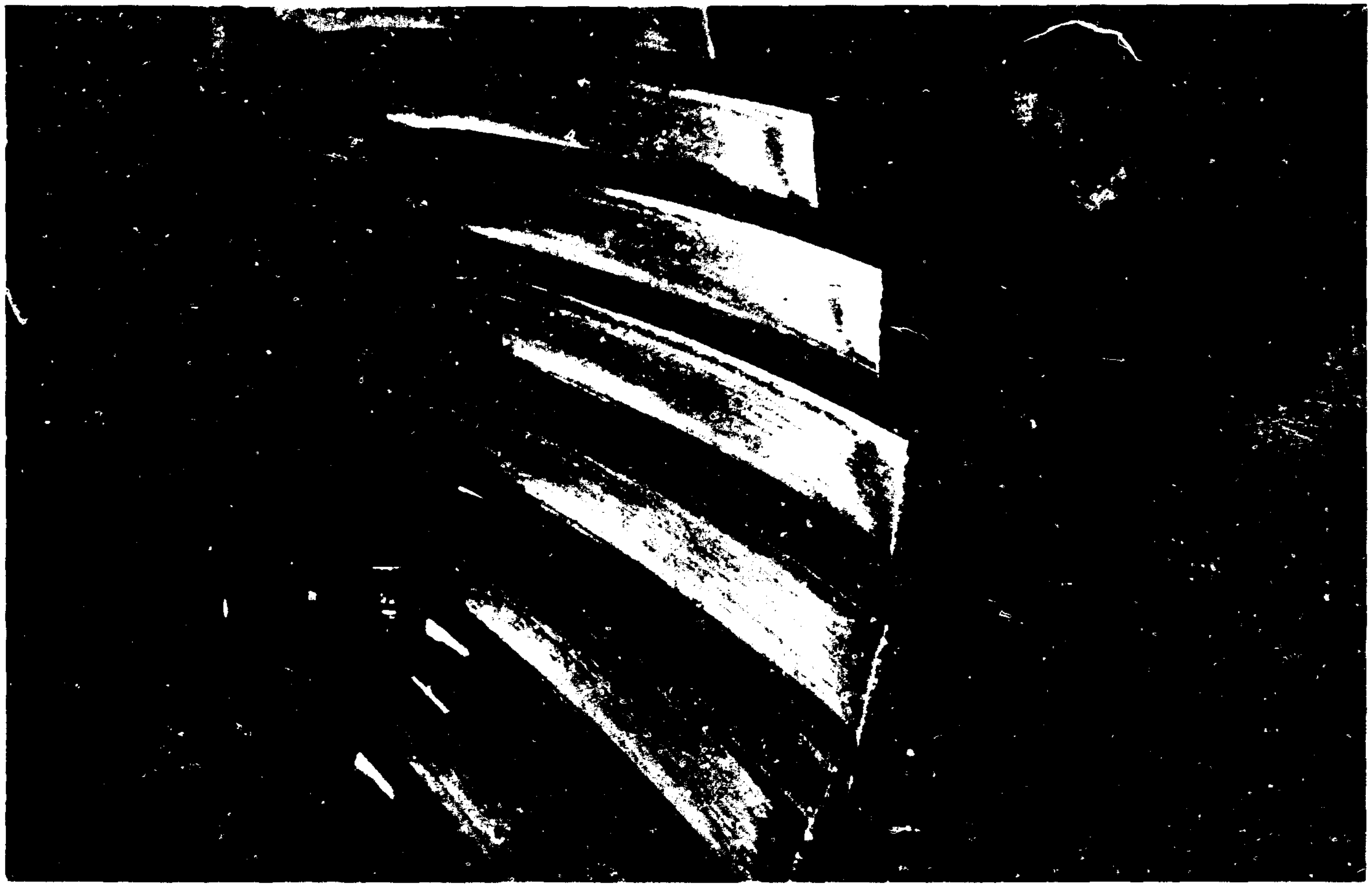
PINION GEAR, DRIVE SIDE
1/4 TON, M151 #2J8693 REAR AXLE
CCL-G-151 20,000 mi.



RING GEAR, DRIVE SIDE
1/4 TON, M151 #2J8693 REAR AXLE
CCL-G-151 20,000 mi.

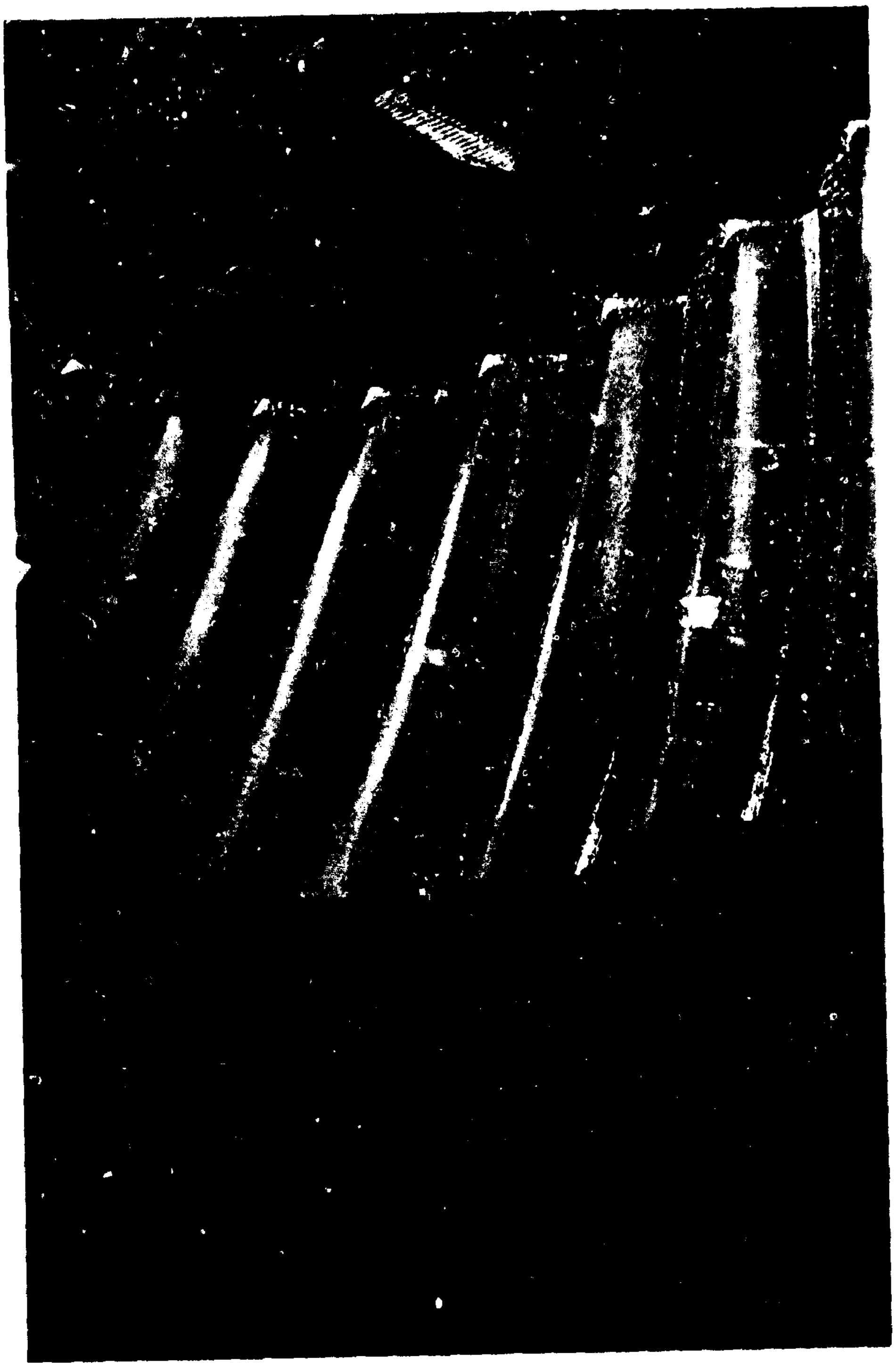
NOT REPRODUCIBLE

PINION GEAR, COAST SIDE
3/4 TON, M37B1 #3B3632 REAR AXLE
CCL-G-148 19,058 mi.

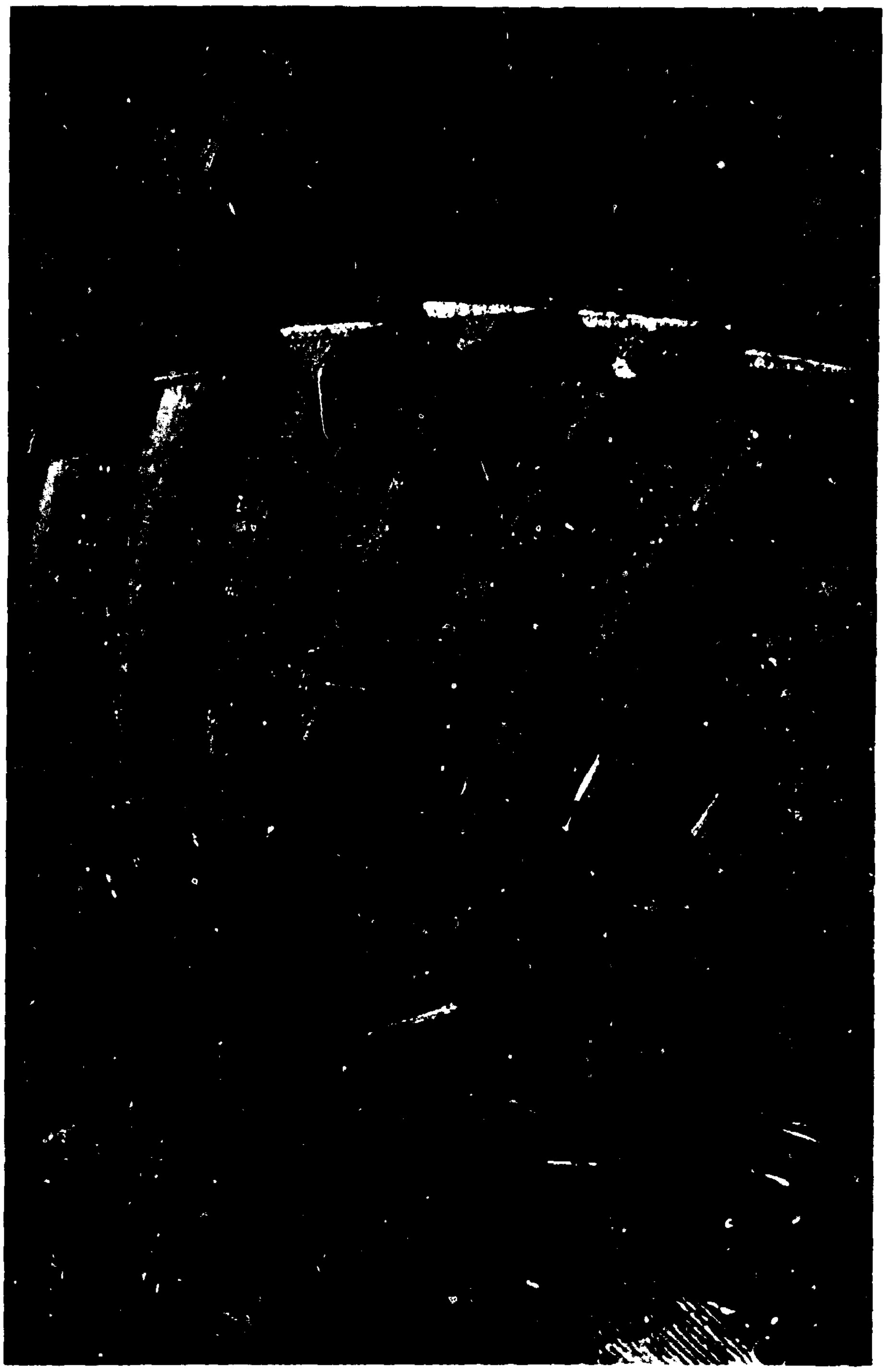


RING GEAR, COAST SIDE
3/4 TON, M37B1 #3B3632 REAR AXLE
CCL-G-148 19,058 mi.

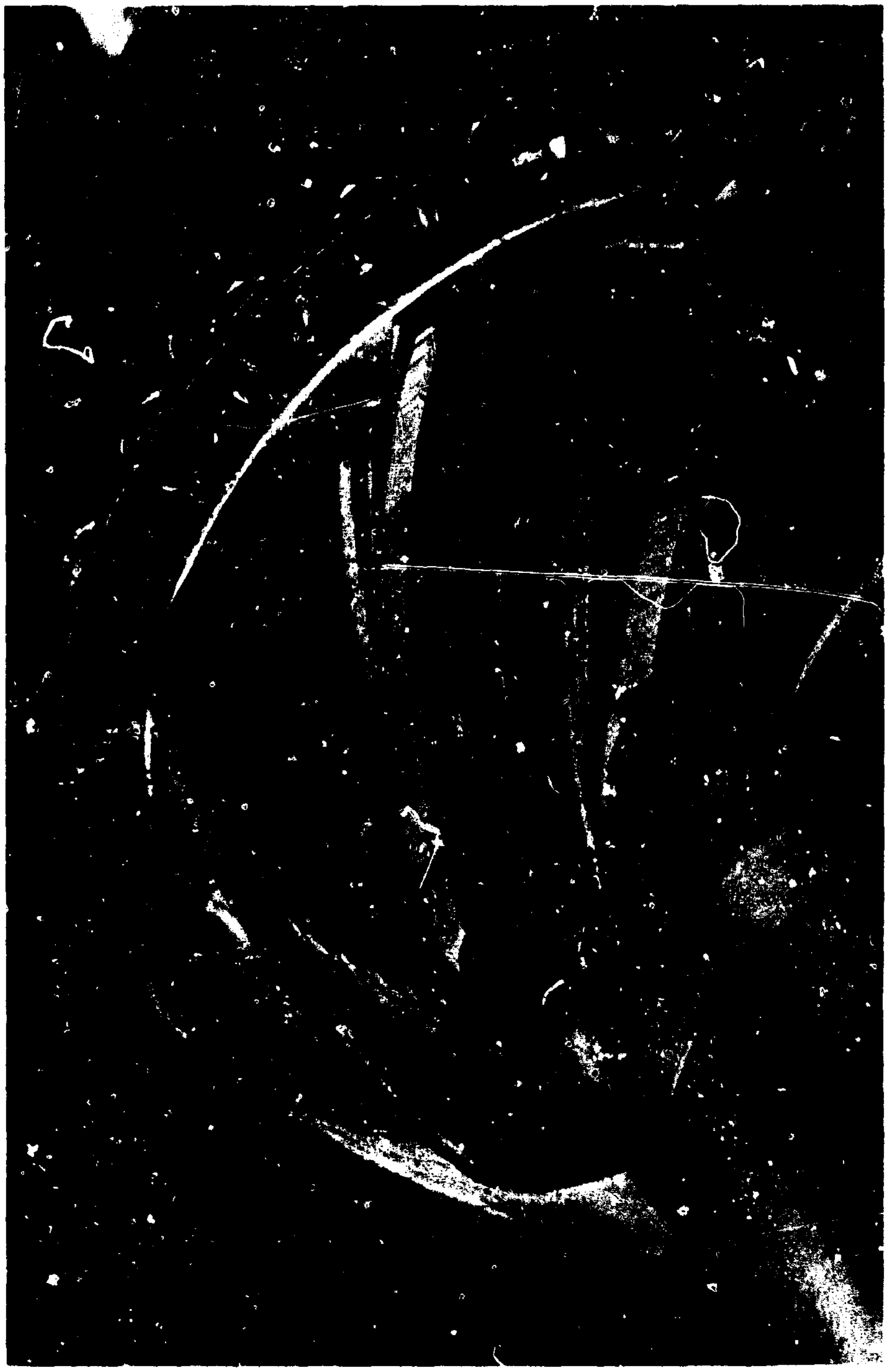
PINION GEAR, COAST SIDE
1-1/4 TCN, M715 #3F3175 REAR AXLE
CCL-G-149 20,000 mi.



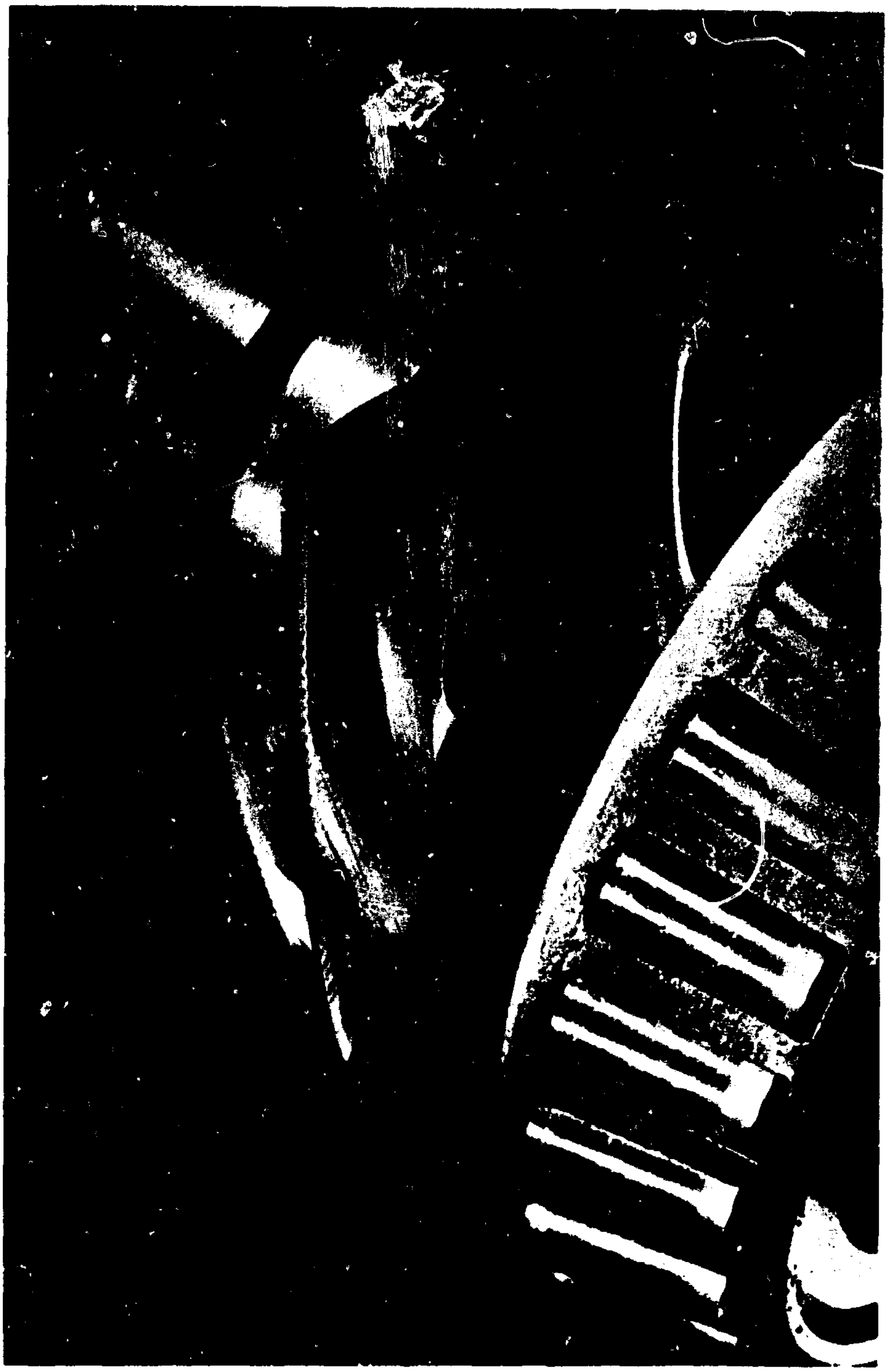
RING GEAR, DRIVE SIDE
1-1/4 TON, M715 #3F3175 REAR AXLE
CCL-G-149 20,000 mi.



RING GEAR, COAST SIDE
1-1/4 TON, M715 #3F3175 REAR AXLE
CCL-G-149 20,000 mi.

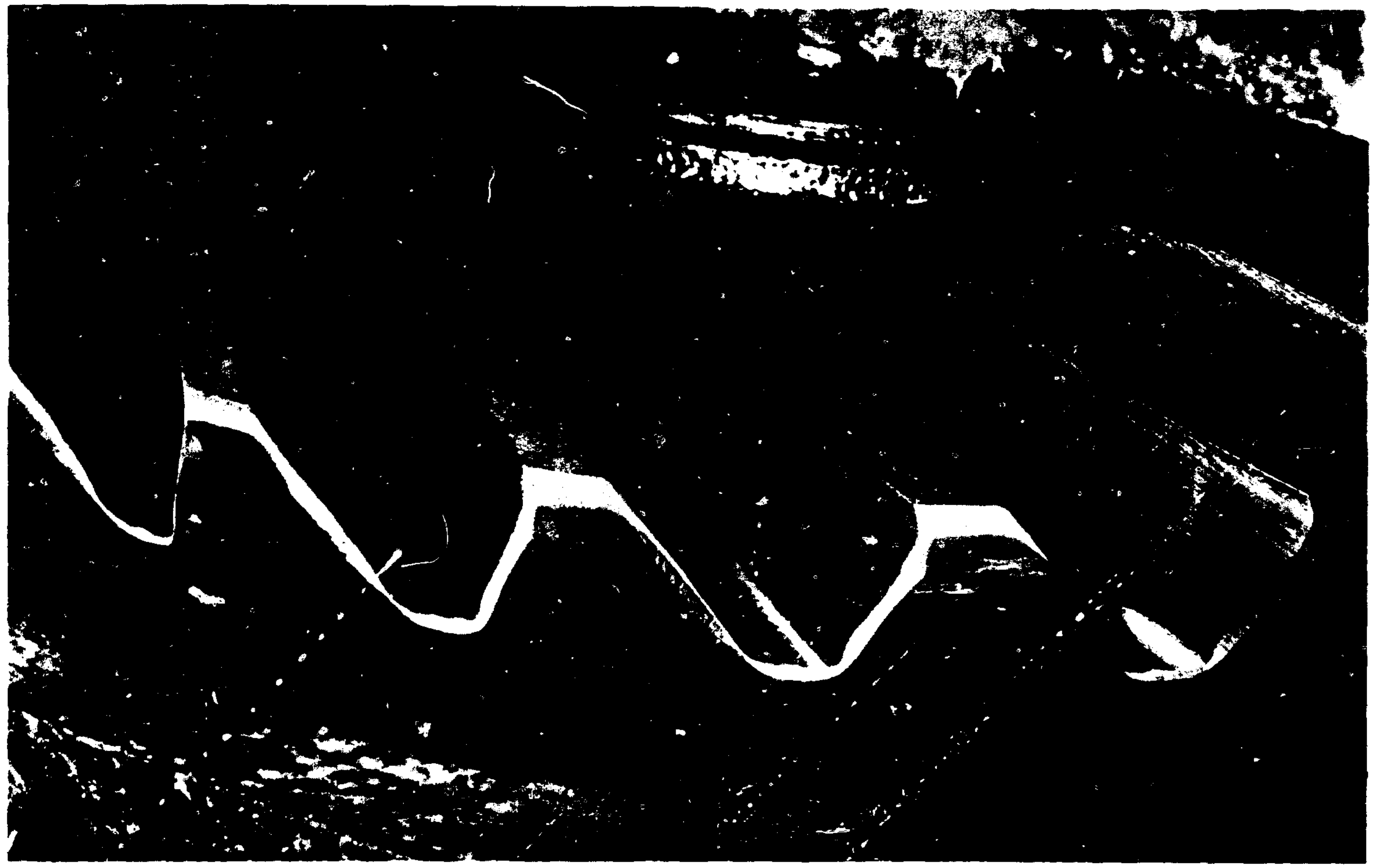


PINION GEAR, DRIVE SIDE
2-1/2 TON, M35A2 #4J2695 REAR AXLE
CCL-G-150 20,000 mi.

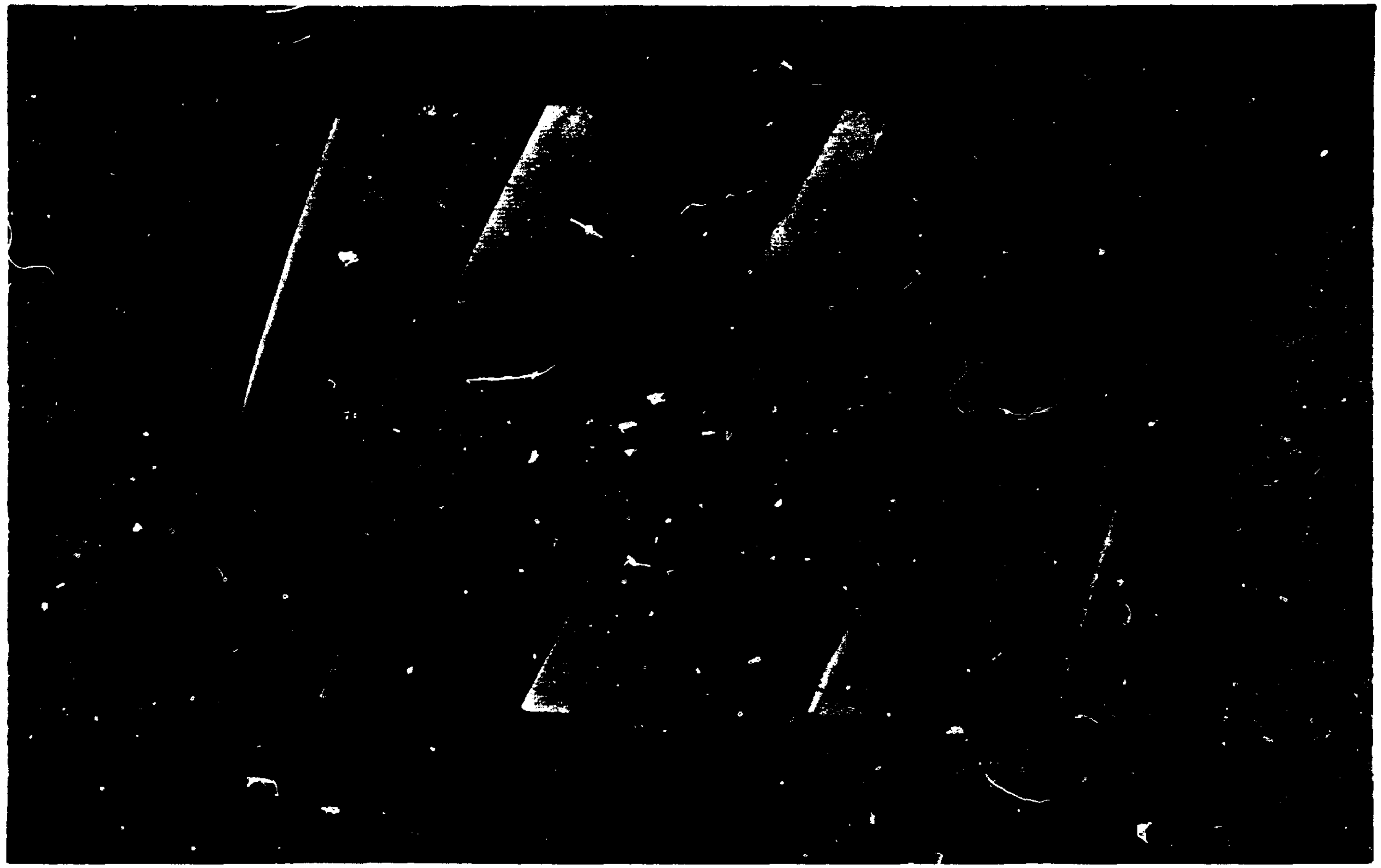


PINION GEAR, COAST SIDE
2-1/2 TON, M35A2 #4J2695 REAR AXLE
CCL-G-150 20,000 mi.

RING GEAR, DRIVE SIDE
2-1/2 TON, M35A2 #4J2695 REAR AXLE
CCL-G-150 20,000 mi.

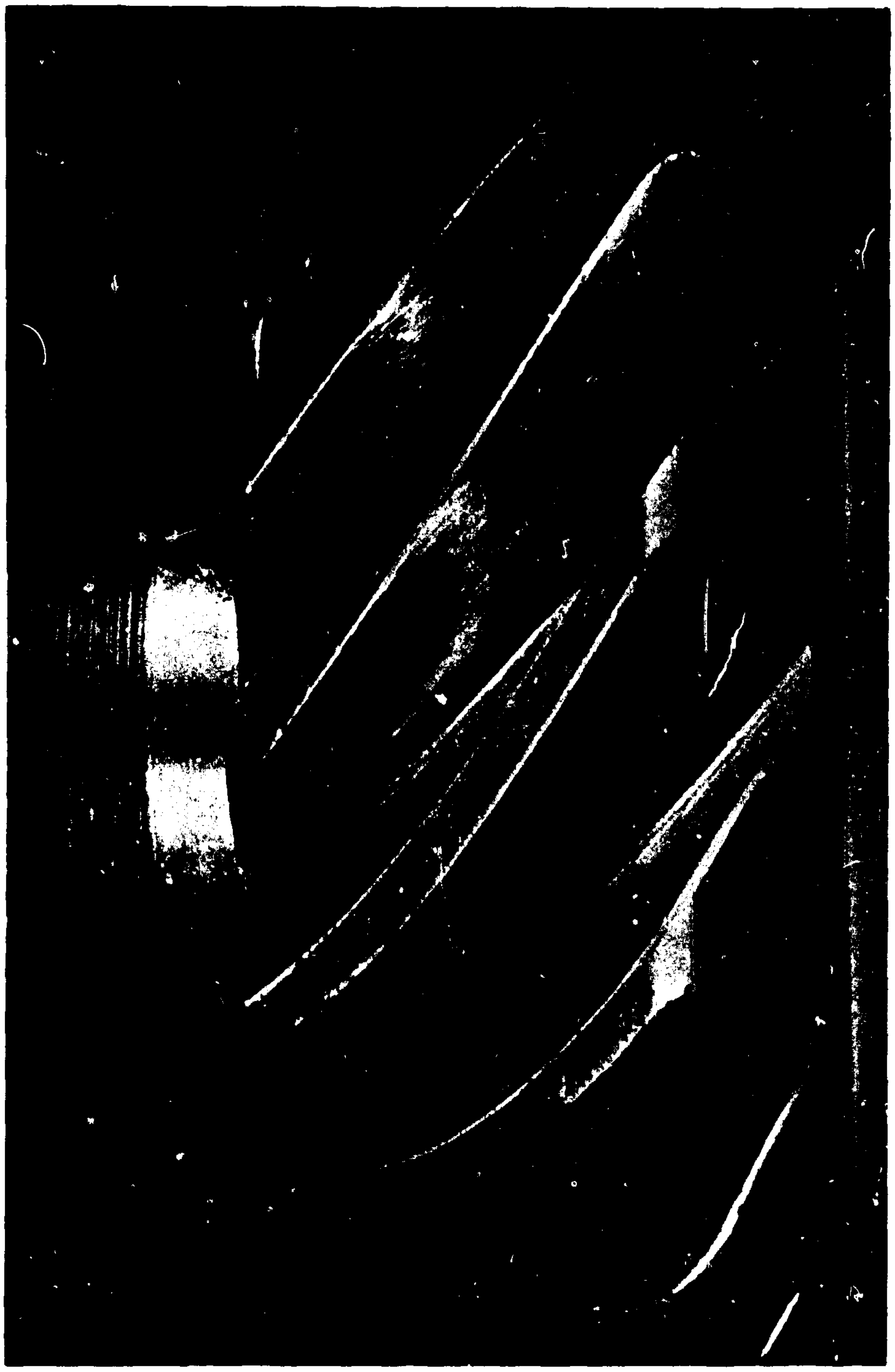


RING GEAR, COAST SIDE
2-1/2 TON, M35A2 #4J2695 REAR AXLE
CCL-G-150 20,000 mi.



UPPER HELICAL GEAR
2-1/2 TON, M35A2 #4J2695 REAR AXLE
CCL-G-150 20,000 mi.

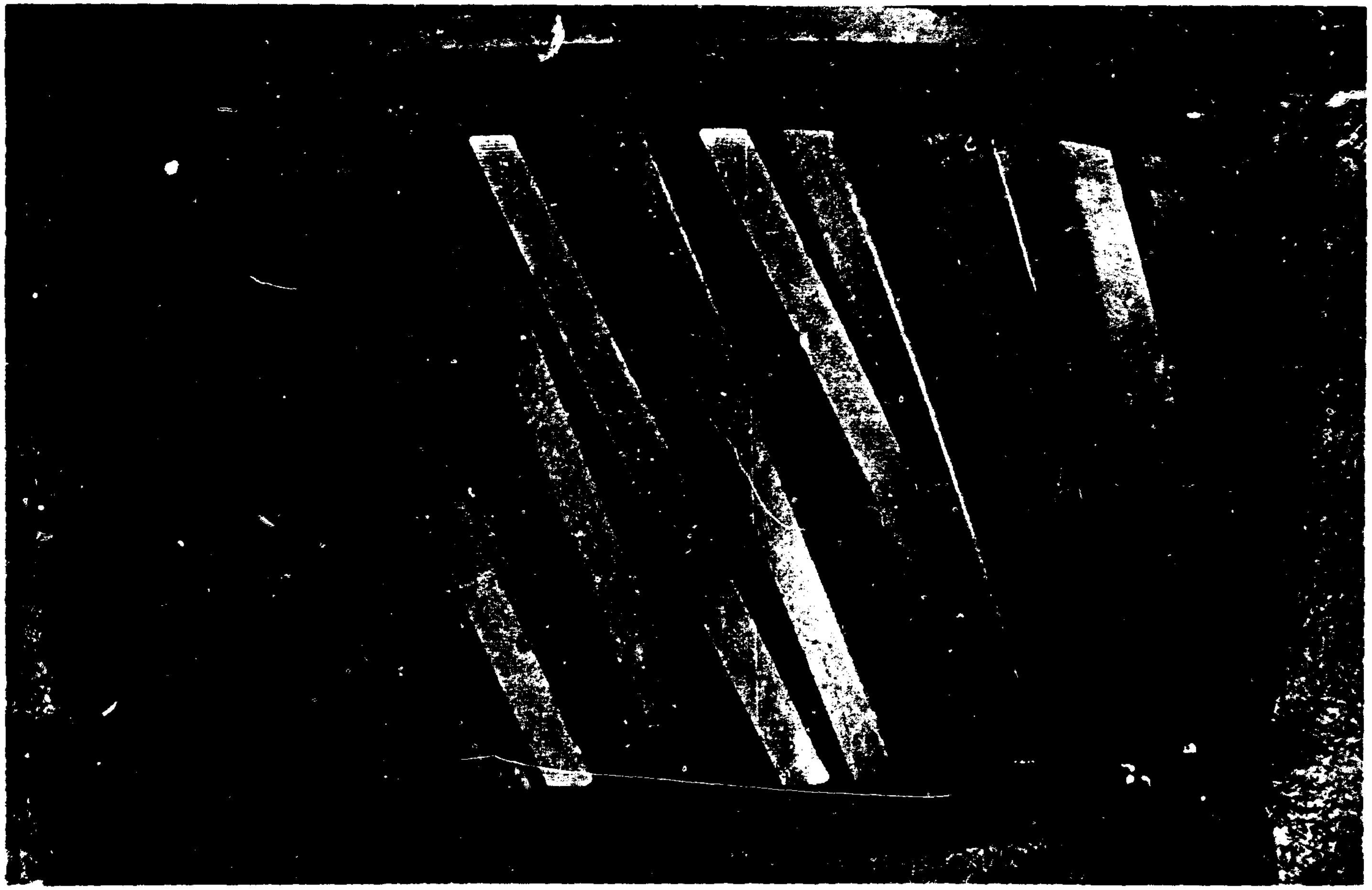
LOWER HELICAL GEAR
2-1/2 TON, M35A2 #4J2695 REAR AXLE
CCL-G-150 20,000 mi.



PINION GEAR, COAST SIDE
5 TON, M54A2 #5E5776 REAR AXLE
CCL-G-150 20,000 mi.

RING GEAR, DRIVE SIDE
5 TON, M54A2 #5E5776 REAR AXLE
CCL-G-150 20,000 mi.

RING GEAR, COAST SIDE
5 TON, M54A2 #5E5776 REAR AXLE
CCL-G-150 20,000 mi.



UPPER HELICAL GEAR
5 TON, M54A2 #5E5776 REAR AXLE
CCL-G-150 20,000 mi.

LOWER HELICAL GEAR
5 TON, M54A2 #5E5776 REAR AXLE
CCL-G-150 20,000 mi.

APPENDIX VI

FINAL EVALUATION OF BRAKE CYLINDERS AND LABORATORY DATA ON ANTIFREEZE

FINAL EVALUATION–BRAKE CYLINDERS–FIELD TEST–SwRI

Vehicle	Reg. No.	Brake Fluid	Water Content, %	Inspection of Brake Parts	Remarks
1/4-Ton, 151A1	2J8600	VV-B-680	20	All cylinders operational. Moderate deposits on pistons and interior of cylinders. Light rust on cylinder walls. Small pits on wheel cylinder pistons. Cups OK.	Master cylinder and pistons are aluminum.
1/4-Ton, 151A1	2J8645	VV-B-680	1.7	All cylinders operational. Moderate deposits on pistons and interior of cylinders. Light rust on cylinder walls. Small pits on wheel cylinder pistons. Cups OK.	Master cylinder and pistons are aluminum.
1/4-Ton, 151A1	2J8666	MIL-H-13910	1.5	Wheel cylinder pistons frozen. Excessive rusting on interior of cylinders. Pistons show moderate to excessive stain and small pits. Cups OK.	Master cylinder and pistons are aluminum.
1/4-Ton, 151A1	2J8669	MIL-H-13910	1.9	Wheel cylinder pistons frozen. Excessive rusting on interior of cylinders. Pistons show moderate to excessive stain and small pits. Cups OK.	Master cylinder and pistons are aluminum.
1/4-Ton, 151A1	2J8693	MIL-P-46046	1.1	Master cylinder rough. Wheel cylinders OK. Pistons OK. Cups OK. All cylinders operational and in very good condition.	Master cylinder and pistons are aluminum.
3/4-Ton, M37	3B3632	VV-B-680	2.6	Master cylinder has small pitted area. Spring rusted in spots. Plating removed from check valve. Moderate gritty sludge. Wheel cylinders on 1-1/4-in. end pistons have heavy pitting and on 1-3/4-in. end, moderate pitting. Cylinders have excessive corrosion. All cylinders operational. Cups OK.	Master cylinder piston anodized. Two wheel cylinder pistons Parkerized.
3/4-Ton, M37	3G6207	VV-B-680	1.8	Excessive corrosion on check valve. Light corrosion on master cylinder. Pistons and cylinders coated with excessive sediment–1-1/4-in. end of cylinders show moderate to excessive corrosion. 1-3/8-in. end shows excessive corrosion. Pistons show excessive corrosion. Cups OK (one cup--heavy scuffing). All cylinders operational.	Anodized master cylinder piston.
1-1/4-Ton, M715	3F3072	VV-B-680	2.2	Light pitting in master cylinder. Plating off check valve. Wheel cylinders show light scattered pitting. Pistons show moderate to heavy pitting. All cylinders operational. Cups OK.	Aluminum master cylinder piston.
1-1/4-Ton, M715	3F3175	MIL-H-13910	1.2	Light rust in master cylinder. Plating removed from check valve. Rust in master cylinder reservoir. Wheel cylinders and pistons coated with excessive residue. Two cylinders moderate to heavy corrosion. Two cylinders light to moderate. Pistons--five moderate pitting, three excessive pitting. Cups OK. All cylinders operational.	Aluminum master cylinder piston.

FINAL EVALUATION–BRAKE CYLINDERS–FIELD TEST–SwRI (Cont'd)

Vehicle	Reg. No.	Brake Fluid	Water Content, %	Inspection of Brake Parts	Remarks
1-1/4-Ton, M715	3F3078	VV-B-680	0.5	Light rust in master cylinder. Plating removed from check valve. Spring is discolored. Light stain and rust areas inside cylinders. Pistons have light to moderate stain and pitting. Cups OK. All cylinders operational.	Aluminum master cylinder piston.
1-1/4-Ton, M715	3F3183	MIL-H-13910	1.3	Light rust in master cylinder. Light corrosion on steel cup protector reservoir shows excessive rust. Wheel cylinders show heavy stain and light to moderate corrosion. Moderate to heavy pitting on pistons. Moderate sediment. [illegible] OK. All cylinders operational.	Aluminum master cylinder piston.
1-1/4-Ton, M715	3F3199	MIL-P-46046	0.7	Master cylinder OK. Master cylinder piston shows excessive corrosion. Some plating off check valve. Wheel cylinders and pistons OK. Cups OK. All cylinders operational.	Aluminum master cylinder piston.
2-1/2-Ton, M35A2	4J2578	VV-B-680	2.4	Excessive pitting on spring and check valve. Light rust on master cylinder. Wheel cylinders and pistons show excessive stain and corrosion. Excessive sediment in fluid. Cups OK. All cylinders operational.	
2-1/2-Ton, M35A2	4J2594	VV-B-680	2.8	Excessive pitting on spring and check valve. Light rust on master cylinder. Excessive sediment in master cylinder. Wheel cylinders and pistons show excessive pitting and stain. Moderate sediment. Cups OK. All cylinders operational.	
2-1/2-Ton, M35A2	4J2695	MIL-P-46046	2.0	Light rust in master cylinder. Moderate sediment. One wheel cylinder excessive corrosion and pitting, four wheel cylinders light corrosion and pitting, one wheel cylinder OK. Six pistons excessive stain and pitting. Six pistons moderate stain and pitting. Cups OK. All cylinders operational.	
2-1/2-Ton, M35A2	4J4609	MIL-P-46046	1.8	Light rust in master cylinder and moderate stain. Excessive sediment. Two wheel cylinders light corrosion, one wheel cylinder excessive, three wheel cylinder OK. Seven pistons show excessive corrosion. Five pistons OK. Moderate sediment. Cups OK. All cylinders operational.	
2-1/2-Ton, M35A2	4J4623	MIL-H-13910	3.3	Excessive corrosion on spring and check valve. Moderate sediment. Excessive rust in wheel cylinders. Six pistons show excessive pitting. Six pistons show light to moderate pitting. Moderate sediment. Cups OK. All cylinders operational.	

FIELD EVALUATION–BRAKE CYLINDERS–FIELD TEST–SwRI (Cont'd)

Vehicle	Reg. No.	Brake Fluid	Water Content, %	Inspection of Brake Parts	Remarks
5-Ton, M54A2	5E5774	VV-B-680	0.8	Light rust in master cylinder. Two nickel cylinders OK. Three cylinders light to moderate corrosion. One wheel cylinder excessive corrosion. Ten pistons moderate pitting, one light, and one heavy pitting. Excessive sediment. Cups OK. All cylinders operational.	Parkerized spring. Anodized MC piston. Front wheel cylinders are electroless nickel.
5-Ton, M54A2	5E5775	VV-B-680	1.4	Two nickel cylinders OK. Two wheel cylinders light corrosion. One wheel cylinder moderate corrosion, and one wheel cylinder excessive corrosion. All cylinders operational. Seven pistons show moderate corrosion, and five show excessive corrosion. Moderate corrosion on MC spring. Cups OK. Excessive sediment.	Parkerized spring. Anodized MC piston. Front wheel cylinders are electroless nickel.
5-Ton, M54A2	5E5776	MIL-P-46046	1.1	Light corrosion on spring in master cylinder. Light to moderate scoring on wheel cylinders. Light pitting on pistons. Light sediment. Cups OK. All cylinders operational.	Anodized MC piston. Front wheel cylinders are electroless nickel.

ARCTIC ANTIFREEZE FIELD TEST–SwRI

Laboratory Evaluation

Reg. No.	Vehicle	Mileage	Solution	pH	R.A.	Maintenance Involving Cooling System
5E5774	5-Ton	50	Clear	7.20	6.90	Refilled at 748 miles, water air manifold cracked, head removed. Heads removed at 10,068 miles to inspect and repair No. 4, No. 5, and No. 6 valves and pistons.
		5,805	H. rust	7.10	6.50	
		12,674	H. rust	6.98	6.90	
		16,001.1	H. rust	6.95	6.50	
		17,451	H. rust	6.95	6.40	
5E5775	5-Ton	92.4	Clear	7.13	6.65	Water manifold bolt off, at 7515 miles 3 gal added. Refilled at 13,189 miles, 2 gal added at 14,073 miles. Oil on top of sample.
		5,798	V.H. rust	7.02	6.40	
		12,000	V.H. rust	6.98	6.40	
		14,095	Sl. rust	7.15	5.80	
5E5776	5-Ton	50	Clear	7.15	6.80	Rear head removed at 7,432 miles. Valves replaced and reseated.
		5,793	V.H. rust	7.15	6.65	
		11,890	V.H. rust	7.12	6.40	
		16,199	V.H. rust	7.10	6.30	
		20,152	V.H. rust	7.08	6.10	
4J2578	2-1/2-Ton	50	Clear	7.20	6.30	
		5,804	Mod. rust	7.23	5.70	
		12,016	V.H. rust	7.23	6.50	
		20,000	Mod. rust	7.25	5.30	
4J2594	2-1/2-Ton	50	Clear	7.20	6.40	
		5,820	H. rust	7.20	6.10	
		12,002	H. rust	7.18	5.90	
		20,000	H. rust	7.18	5.70	
4J2695	2-1/2-Ton	50	Clear	7.12	6.60	Engine pulled at 11,480 to replace broken crankshaft. Thermostat replaced at 16.412 miles–no overheating.
		5,820	Med. rust	7.10	6.30	
		11,993	H. rust	7.10	6.70	
		20,000	Mod. rust	7.08	6.50	
4J4609	2-1/2-Ton	50	Clear	7.22	6.50	
		5,800	H. rust	7.25	5.80	
		12,012	V.H. rust	7.22	5.60	
		20,000	V.H. rust	7.17	5.10	
4J4623	2-1/2-Ton	50	Clear	7.20	7.00	
		5,805	H. rust	7.27	6.20	
		12,000	H. rust	7.28	6.00	
		20,000	Mod. rust	7.22	5.70	
3F3072	1-1/4-Ton	50	Clear	7.22	5.90	
		5,816	Sl. cloudy	7.22	5.50	
		12,034	Sl. cloudy	7.28	6.40	
		20,000	Sl. cloudy	7.12	5.20	
3F3078	1-1/4-Ton	50	Clear	7.35	5.60	
		5,799	Sl. cloudy	7.28	5.20	
		11,935	Sl. cloudy	7.17	4.90	
		20,000	Sl. cloudy	7.22	4.80	
3F3175	1-1/4-Ton	50	Clear	7.38	6.00	
		5,787	Sl. cloudy	7.22	5.30	
		12,060	Mod. cloudy	7.13	4.80	
		20,000	Mod. cloudy	7.25	4.10	
3F3183	1-1/4-Ton	No initial sample received.				
		5,801	Sl. cloudy	7.58	4.30	
		12,177	Clear	7.53	4.10	
		20,000	Clear	7.48	4.20	
3F3199	1-1/4-Ton	50	Clear	7.52	4.50	
		5,800	Sl. cloudy	7.50	4.10	
		12,143	Sl. cloudy	7.43	3.80	
		20,000	Sl. cloudy	7.38	3.90	

ARCTIC ANTIFREEZE FIELD TEST–SwRI (Cont'd)

Laboratory Evaluation

Reg. No.	Vehicle	Mileage	Solution	pH	R.A.	Maintenance Involving Cooling System
3B3632	3/4-Ton	67	Clear	7.25	6.00	Pump replaced at 7,182 miles. Pump replaced at 11,543 miles
		5,807	Clear	7.20	5.80	
		12,000.8	Clear	7.12	5.80	
		20,000	Clear	7.12	6.40	
3G6207	3/4-Ton	48.7	Rusty	7.18	5.90	Engine rebuilt at 5,792 miles. New No. 4 intake valve installed, and No. 4 intake and exhaust valve seats ground at 15,874 miles.
		5,793	H. rust	7.07	6.10	
		12,001	H. rust	6.98	6.00	
		20,000	Sl. rust	7.02	6.40	
2J8600	1/4-Ton	63.7	Clear	7.22	6.30	
		5,856	Sl. rust	7.15	6.10	
		12,001.3	Sl. rust	7.10	6.20	
		20,000	Sl. rust	7.05	5.50	
2J8645	1/4-Ton	55.8	Clear	7.15	6.50	
		5,802	Clear	7.15	6.20	
		20,000	V.Sl. rust	7.08	5.50	
2J8666	1/4-Ton	50	Clear	7.22	6.50	
		5,803	Clear	7.18	6.10	
		12,005	Clear	7.20	5.50	
		20,000	Clear	7.15	4.70	
2J8669	1/4-Ton	50	Clear	7.12	6.50	
		5,940	Clear	7.10	6.00	
		20,000	Clear	6.98	5.20	
2J8693	1/4-Ton	50	Clear	7.22	6.50	
		5,802	Clear	7.15	6.10	
		11,998	V.Sl. cloudy	7.08	6.00	
		20,000	Clear	7.02	5.40	

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13. ABSTRACT

A 20-truck fleet test of general purpose vehicles was conducted with four different engine oils, four gear lubricants, four greases, three brake fluids, an arctic antifreeze, two grades of gasoline, and two compression ignition fuels over a test course ranging from highway operation, hilly cross-country terrain, to operation in deep sand, in order to establish the compatibility of the various test materials with typical vehicles in the Army inventory. In general, the majority of the materials performed satisfactorily although specific compatibility problems were noted with engine oils in the 5-ton truck and gear oils in the 1/4-ton M151 jeeps. Both federal and Military specification brake fluids gave satisfactory operational performance but tended to cause corrosion and gum buildup during inactive periods, whereas a military specification preservative fluid tested caused less corrosion and gum with satisfactory operation within its temperature limits. The military specification antifreeze utilized performed adequately in lower-heat-output engine systems but provided marginal to poor performance in the higher-heat-output engine systems.

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Fleet Test						
General Purpose Army Vehicles						